REPORT

OF THE

EIGHTY-SECOND MEETING OF THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

DUNDEE: 1912

SEPTEMBER 4–11

LONDON
JOHN MURRAY, ALBEMARLE STREET
1913

Office of the Association: Burlington House, London, W.

CONTENTS.

* Particulars for early Meetings not furnished in the following Tables will be found in Volumes for 1911 and previous years.

LIST OF PLATES.

OFFICERS AND COUNCIL, 1912–1913.

PATRON

HIS MAJESTY THE KING.

PRESIDENT.

PROFESSOR E A SCHAFER, LL D, D Sc, M D, F R S

VICE-PRESIDENTS.

The Hon the Lord Provost of Dundee and Lord Lieutenant of the County of the City of Dundee
The Right Hon the EARL OF STRATHMORE, Lord Lieutenant of the County of Forfar
JAMES FERGUSON, K C, Sheriff of Forfarshire
The Right Rev the Moderator of the General Assembly of the Church of Scotland
The Right Hon the EARL OF CAMPERDOWN
The Right Hon LORD KINNAIRD
Sir WILLIAM OGILVY DALGLEISH, Bart, of Errol Park.
Sir JAMES DONALDSON, LL D, Principal of the University of St Andrews
Sir GEORGE BAXTER, LL D.
The Right Rev the Moderator of the General Assembly of the United Free Church of Scotland
The Right Rev BISHOP ROBBERDS, D D, Bishop of Brechin, and Primus of the Episcopal Church of Scotland
The Right Rev Bishop MACFARLANE, D D, R C Bishop of Dunkeld
J YULE MACKAY, M D, LL D, Principal of University College, Dundee.
The President of the Dundee Chamber of Commerce.
Sir J. K. CAIRD, Bart, LL.D

PRESIDENT ELECT

*Sir OLIVER J. LODGE, D Sc, LL D, F R S.

VICE-PRESIDENTS ELECT

The Right Hon the Lord Mayor of Birmingham (Lieut-Col ERNEST MARTINEAU, M A)
The Most Hon the MARQUESS OF NORTHAMPTON, K G, Lord Lieutenant of Warwicksnire
The Worshipful the High Sheriff of Warwickshire (Sir FRANCIS E WALLER, Bart)
The Right Hon the EARL OF COVENTRY, Lord-Lieutenant of Worcestershire
The Right Hon the EARL OF DARTMOUTH, V D, Lord-Lieutenant of Staffordshire
The Right Rev the LORD BISHOP OF BIRMINGHAM (Dr HENRY RUSSELL WAKEFIELD)
The Right Hon JOSEPH CHAMBERLAIN, LL D, D C L, M P, F R S, Chancellor of the University of Birmingham
GILBERT BARLING, M B, F R C S, Vice-Chancellor of the University of Birmingham.
The Right Hon JESSE COLLINGS, M P., Hon President of the Birmingham Chamber of Commerce
Alderman the Right Hon WILLIAM KENRICK
Alderman W H BOWATER, Deputy Lord Mayor of Birmingham
Professor J H POYNTING, F R S
Professor CHARLES LAPWORTH, F R.S

GENERAL TREASURER

Professor JOHN PERRY, D Sc, LL D, F R S

GENERAL SECRETARIES.

Major P A MACMAHON, D Sc, LL D, F R S | Professor W. A HERDMAN, D Sc, F R S

ASSISTANT SECRETARY

O J R HOWARTH, M A, Burlington House, London, W

CHIEF CLERK AND ASSISTANT TREASURER

H C STEWARDSON, Burlington House, London, W.

LOCAL TREASURERS FOR THE MEETING AT BIRMINGHAM

Sir G. H. KENRICK | NEVILLE CHAMBERLAIN.

LOCAL SECRETARIES FOR THE MEETING AT BIRMINGHAM

Prof F W GAMBLE, F R S
HOWARD HEATON
JOHN HUMPHREYS
W BYNG KENRICK.

* Sir WILLIAM H WHITE, K C B, LL D, Sc D, D Sc, D Eng, F R S., was appointed President for 1913-14 (Birmingham Meeting) by the General Committee at the Dundee Meeting. He died on the 27th February 1913

[P.T.O.

ORDINARY MEMBERS OF THE COUNCIL.

ARMSTRONG, Professor H E, F R S
BRABROOK, Sir EDWARD, C B
CLERK, Dr. DUGALD, F R S.
CRAIGIE, Major P G, C.B
CROOKE, W, B A.
DENDY, Professor A, F R.S.
FARMER, Professor J B, F R S
GRIFFITHS, Principal E H., F R.S
HADDON, Dr A. C, F R S
HALL, A D, F R S
HALLIBURTON, Professor W. D, F R S
HARTLAND, E SIDNEY, F S.A.
LODGE, Sir OLIVER, F R S.
LYONS, Captain H G, F R S
MARR, Dr J. E, F R S.
MELDOLA, Professor R, F.R S.
MITCHELL, Dr P CHALMERS, F R S.
MYRES, Professor J. L, M A
PRAIN, Sir DAVID, C I.E, F R S
SHERRINGTON, Professor C S, F R S.
TEALL, J J H, F R S
THOMPSON, Dr SILVANUS P., F R S
TROUTON, Professor F T, F R S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Lord AVEBURY, D C L, LL D, F.R S, F L S
The Right Hon Lord RAYLEIGH, O M, M A, D C L, LL D., F R S, F.R.A S
Sir ARTHUR W. RÜCKER, M A, D Sc, LL D, F R S

PAST PRESIDENTS OF THE ASSOCIATION

Lord Avebury, D C L, F R S
Lord Rayleigh, D C L, F R S
Sir H E Roscoe, D C L, F R S
Sir A Geikie, K C B, Pres R S
Sir William Crookes, O M, F R S
Sir W. Turner, K C B, F.R.S.
Sir A W Rücker, D Sc, F R S
Sir James Dewar, LL D, F R S
Sir Norman Lockyer, K C B, F R S
Arthur J Balfour, D C L, F R S
Sir E Ray Lankester, K C B, F R S
Sir David Gill, K C B, F R S.
Sir Francis Darwin, F R S
Sir J J Thomson, O M, F R S
Prof T G Bonney, Sc D, F R S.
Sir W Ramsay, K C B, F.R S.

PAST GENERAL OFFICERS OF THE ASSOCIATION

P L Sclater, Ph D, F R S
Prof. T G Bonney, Sc.D, F R S
A. Vernon Harcourt, D.C L, F R S
Sir A W Rücker, D Sc, F R S
Prof E A Schafer, F.R S
Dr. D H. Scott, M A., F R S
Dr G Carey Foster, F.R.S
Dr. J G Garson.

AUDITORS.

Sir Edward Brabrook, C B | Professor H. McLeod, LL D, F R.S.

RULES OF THE BRITISH ASSOCIATION.

[*Adopted by the General Committee at Leicester*, 1907, *with subsequent amendments*]

Chapter I.

Objects and Constitution.

1 The objects of the British Association for the Advancement of Science are · To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another and with foreign philosophers, to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress Objects

The Association contemplates no invasion of the ground occupied by other Institutions

2. The Association shall consist of Members, Associates, and Honorary Corresponding Members Constitution

The governing body of the Association shall be a General Committee, constituted as hereinafter set forth; and its affairs shall be directed by a Council and conducted by General Officers appointed by that Committee

3. The Association shall meet annually, for one week or longer, and at such other times as the General Committee may appoint The place of each Annual Meeting shall be determined by the General Committee not less than two years in advance, and the arrangements for these meetings shall be entrusted to the Officers of the Association. Annual Meetings

Chapter II.

The General Committee.

1. The General Committee shall be constituted of the following persons.— Constitution

(1) *Permanent Members*—

(*a*) Past and present Members of the Council, and past and present Presidents of the Sections.

(*b*) Members who, by the publication of works or papers, have furthered the advancement of knowledge in any of those departments which are assigned to the Sections of the Association.

(ii) *Temporary Members*—

(*a*) Vice-Presidents and Secretaries of the Sections.
(*b*) Honorary Corresponding Members, foreign representatives, and other persons specially invited or nominated by the Council or General Officers.
(*c*) Delegates nominated by the Affiliated Societies.
(*d*) Delegates—not exceeding altogether three in number—from Scientific Institutions established at the place of meeting.

Admission

2. The decision of the Council on the qualifications and claims of any Member of the Association to be placed on the General Committee shall be final.

(i) Claims for admission as a Permanent Member must be lodged with the Assistant Secretary at least one month before the Annual Meeting.
(ii) Claims for admission as a Temporary Member may be sent to the Assistant Secretary at any time before or during the Annual Meeting

Meetings.

3 The General Committee shall meet twice at least during every Annual Meeting In the interval between two Annual Meetings, it shall be competent for the Council at any time to summon a meeting of the General Committee

Functions

4. The General Committee shall

(i) Receive and consider the report of the Council.
(ii) Elect a Committee of Recommendations
(iii) Receive and consider the report of the Committee of Recommendations.
(iv) Determine the place of the Annual Meeting not less than two years in advance.
(v) Determine the date of the next Annual Meeting.
(vi) Elect the President and Vice-Presidents, Local Treasurer, and Local Secretaries for the next Annual Meeting
(vii) Elect Ordinary Members of Council.
(viii) Appoint General Officers
(ix) Appoint Auditors
(x) Elect the officers of the Conference of Delegates.
(xi) Receive any notice of motion for the next Annual Meeting.

Chapter III.

Committee of Recommendations.

1. * The *ex officio* Members of the Committee of Recommendations are the President and Vice-Presidents of the Association, the President of each Section at the Annual Meeting, the Chairman of the Conference of Delegates, the General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years. Constitution

An Ordinary Member of the Committee for each Section shall be nominated by the Committee of that Section

If the President of a Section be unable to attend a meeting of the Committee of Recommendations, the Sectional Committee may appoint a Vice-President, or some other member of the Committee, to attend in his place, due notice of such appointment being sent to the Assistant Secretary.

2. Every recommendation made under Chapter IV. and every resolution on a scientific subject, which may be submitted to the Association by any Sectional Committee, or by the Conference of Delegates, or otherwise than by the Council of the Association, shall be submitted to the Committee of Recommendations If the Committee of Recommendations approve such recommendation, they shall transmit it to the General Committee, and no recommendation shall be considered by the General Committee that is not so transmitted Functions

Every recommendation adopted by the General Committee shall, if it involve action on the part of the Association, be transmitted to the Council; and the Council shall take such action as may be needful to give effect to it, and shall report to the General Committee not later than the next Annual Meeting

Every proposal for establishing a new Section or Sub-Section, for altering the title of a Section, or for any other change in the constitutional forms or fundamental rules of the Association, shall be referred to the Committee of Recommendations for their consideration and report.

3 The Committee of Recommendations shall assemble, for the despatch of business, on the Monday of the Annual Meeting, and, if necessary, on the following day Their Report must be submitted to the General Committee on the last day of the Annual Meeting. Procedure

* Amended by the General Committee at Winnipeg, 1909

CHAPTER IV.

Research Committees.

Procedure

1 Every proposal for special research, or for a grant of money in aid of special research, which is made in any Section, shall be considered by the Committee of that Section, and, if such proposal be approved, it shall be referred to the Committee of Recommendations

Constitution

In consequence of any such proposal, a Sectional Committee may recommend the appointment of a Research Committee, composed of Members of the Association, to conduct research or administer a grant in aid of research, and in any case to report thereon to the Association; and the Committee of Recommendations may include such recommendation in their report to the General Committee.

2. Every appointment of a Research Committee shall be proposed at a meeting of the Sectional Committee and adopted at a subsequent meeting. The Sectional Committee shall settle the terms of reference and suitable Members to serve on it, which must be as small as is consistent with its efficient working; and shall nominate a Chairman and a Secretary. Such Research Committee, if appointed, shall have power to add to their numbers.

Proposals by Sectional Committees

3 The Sectional Committee shall state in their recommendation whether a grant of money be desired for the purposes of any Research Committee, and shall estimate the amount required.

All proposals sanctioned by a Sectional Committee shall be forwarded by the Recorder to the Assistant Secretary not later than noon on the Monday of the Annual Meeting for presentation to the Committee of Recommendations.

Tenure

4 Research Committees are appointed for one year only. If the work of a Research Committee cannot be completed in that year, application may be made through a Sectional Committee at the next Annual Meeting for reappointment, with or without a grant—or a further grant—of money.

Reports

5 Every Research Committee shall present a Report, whether interim or final, at the Annual Meeting next after that at which it was appointed or reappointed. Interim Reports, whether intended for publication or not, must be submitted in writing Each Sectional Committee shall ascertain whether a Report has been made by each Research Committee appointed on their recommendation, and shall report to the Committee of Recommendations on or before the Monday of the Annual Meeting.

GRANTS. (*a*) Drawn by Chairman.

6. In each Research Committee to which a grant of money has been made, the Chairman is the only person entitled to call on the General Treasurer for such portion of the sum granted as from time to time may be required.

(*b*) Expire on June 30.

Grants of money sanctioned at the Annual Meeting expire on June 30 following. The General Treasurer is not authorised, after that date, to allow any claims on account of such grants.

(*c*) Accounts and balance in hand.

The Chairman of a Research Committee must, before the Annual Meeting next following the appointment of the Research Committee, forward to the General Treasurer a statement of the sums that have been received and expended, together with vouchers. The Chairman must then return the balance of the grant, if any, which remains unexpended; provided that a Research Committee may, in the first year of its appointment only, apply for leave to retain an unexpended balance when or before its report is presented, due reason being given for such application.*

(*d*) Additional Grant.

When application is made for a Committee to be re-appointed, and to retain the balance of a former grant, and also to receive a further grant, the amount of such further grant is to be estimated as being sufficient, together with the balance proposed to be retained, to make up the amount desired.

(*e*) *Caveat.*

In making grants of money to Research Committees, the Association does not contemplate the payment of personal expenses to the Members.

A Research Committee, whether or not in receipt of a grant, shall not raise money, in the name or under the auspices of the Association, without special permission from the General Committee.

Disposal of specimens, apparatus, &c.

7. Members and Committees entrusted with sums of money for collecting specimens of any description shall include in their Reports particulars thereof, and shall reserve the specimens thus obtained for disposal, as the Council may direct.

Committees are required to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus is likely to be useful for continuing the research in question or for other specific purposes.

All instruments, drawings, papers, and other property of the Association, when not in actual use by a Committee, shall be deposited at the Office of the Association.

* Amended by the General Committee at Dundee, 1912.

Chapter V.

The Council.

Constitution

1. The Council shall consist of *ex officio* Members and of Ordinary Members elected annually by the General Committee.

(i) The *ex officio* Members are—the Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting

(ii) The Ordinary Members shall not exceed twenty-five in number Of these, not more than twenty shall have served on the Council as Ordinary Members in the previous year.

Functions.

2. The Council shall have authority to act, in the name and on behalf of the Association, in all matters which do not conflict with the functions of the General Committee

In the interval between two Annual Meetings, the Council shall manage the affairs of the Association and may fill up vacancies among the General and other Officers, until the next Annual Meeting.

The Council shall hold such meetings as they may think fit, and shall in any case meet on the first day of the Annual Meeting, in order to complete and adopt the Annual Report, and to consider other matters to be brought before the General Committee.

The Council shall nominate for election by the General Committee, at each Annual Meeting, a President and General Officers of the Association.

Suggestions for the Presidency shall be considered by the Council at the Meeting in February, and the names selected shall be issued with the summonses to the Council Meeting in March, when the nomination shall be made from the names on the list

The Council shall have power to appoint and dismiss such paid officers as may be necessary to carry on the work of the Association, on such terms as they may from time to time determine.

3. Election to the Council shall take place at the same time as that of the Officers of the Association. Elections

(i) At each Annual Election, the following Ordinary Members of the Council shall be ineligible for re-election in the ensuing year

(*a*) Three of the Members who have served for the longest consecutive period, and

(*b*) Two of the Members who, being resident in or near London, have attended the least number of meetings during the past year

Nevertheless, it shall be competent for the Council, by an unanimous vote, to reverse the proportion in the order of retirement above set forth

(ii) The Council shall submit to the General Committee, in their Annual Report, the names of twenty-three Members of the Association whom they recommend for election as Members of Council.

(iii) Two Members shall be elected by the General Committee, without nomination by the Council; and this election shall be at the same meeting as that at which the election of the other Members of the Council takes place.

Any member of the General Committee may propose another member thereof for election as one of these two members of Council, and, if only two are so proposed, they shall be declared elected, but, if more than two are so proposed, the election shall be by show of hands, unless five members at least require it to be by ballot.

Chapter VI

The President, General Officers, and Staff

1. The President assumes office on the first day of the Annual Meeting, when he delivers a Presidential Address. He resigns office at the next Annual Meeting, when he inducts his successor into the Chair. The President.

The President shall preside at all meetings of the Association or of its Council and Committees which he attends in his capacity as President. In his absence, he shall be represented by a Vice-President or past President of the Association

2. The General Officers of the Association are the General Treasurer and the General Secretaries. General Officers

It shall be competent for the General Officers to act, in the name of the Association, in any matter of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

The General Treasurer. 3. The General Treasurer shall be responsible to the General Committee and the Council for the financial affairs of the Association

The General Secretaries. 4. The General Secretaries shall control the general organisation and administration, and shall be responsible to the General Committee and the Council for conducting the correspondence and for the general routine of the work of the Association, excepting that which relates to Finance.

The Assistant Secretary 5 The Assistant Secretary shall hold office during the pleasure of the Council He shall act under the direction of the General Secretaries, and in their absence shall represent them He shall also act on the directions which may be given him by the General Treasurer in that part of his duties which relates to the finances of the Association

The Assistant Secretary shall be charged, subject as aforesaid (i) with the general organising and editorial work, and with the administrative business of the Association, (ii) with the control and direction of the Office and of all persons therein employed; and (iii) with the execution of Standing Orders or of the directions given him by the General Officers and Council He shall act as Secretary, and take Minutes, at the meetings of the Council, and at all meetings of Committees of the Council, of the Committee of Recommendations, and of the General Committee

Assistant Treasurer. 6 The General Treasurer may depute one of the Staff, as Assistant Treasurer, to carry on, under his direction, the routine work of the duties of his office

The Assistant Treasurer shall be charged with the issue of Membership Tickets, the payment of Grants, and such other work as may be delegated to him.

CHAPTER VII.

Finance.

Financial Statements. 1. The General Treasurer, or Assistant Treasurer, shall receive and acknowledge all sums of money paid to the Association. He shall submit, at each meeting of the Council, an *interim* statement of his Account; and, after

June 30 in each year, he shall prepare and submit to the General Committee a balance-sheet of the Funds of the Association.

2. The Accounts of the Association shall be audited, annually, by Auditors appointed by the General Committee. Audit.

3 The General Treasurer shall make all ordinary payments authorised by the General Committee or by the Council. Expenditure.

4 The General Treasurer is empowered to draw on the account of the Association, and to invest on its behalf, part or all of the balance standing at any time to the credit of the Association in the books of the Bank of England, either in Exchequer Bills or in any other temporary investment, and to change, sell, or otherwise deal with such temporary investment as may seem to him desirable. Investments.

5. In the event of the General Treasurer being unable, from illness or any other cause, to exercise the functions of his office, the President of the Association for the time being and one of the General Secretaries shall be jointly empowered to sign cheques on behalf of the Association Cheques

CHAPTER VIII.

The Annual Meetings

1 Local Committees shall be formed to assist the General Officers in making arrangements for the Annual Meeting, and shall have power to add to their number. Local Officers and Committees

2. The General Committee shall appoint, on the recommendation of the Local Reception or Executive Committee for the ensuing Annual Meeting, a Local Treasurer or Treasurers and two or more Local Secretaries, who shall rank as officers of the Association, and shall consult with the General Officers and the Assistant Secretary as to the local arrangements necessary for the conduct of the meeting The Local Treasurers shall be empowered to enrol Members and Associates, and to receive subscriptions.

3. The Local Committees and Sub-Committees shall undertake the local organisation, and shall have power to act in the name of the Association in all matters pertaining to the local arrangements for the Annual Meeting other than the work of the Sections. Functions.

CHAPTER IX.

The Work of the Sections.

THE SECTIONS.

1. The scientific work of the Association shall be transacted under such Sections as shall be constituted from time to time by the General Committee.

It shall be competent for any Section, if authorised by the Council for the time being, to form a Sub-Section for the purpose of dealing separately with any group of communications addressed to that Section.

Sectional Officers.

2. There shall be in each Section a President, two or more Vice-Presidents, and two or more Secretaries They shall be appointed by the Council, for each Annual Meeting in advance, and shall act as the Officers of the Section from the date of their appointment until the appointment of their successors in office for the ensuing Annual Meeting.

Of the Secretaries, one shall act as Recorder of the Section, and one shall be resident in the locality where the Annual Meeting is held.

Rooms

3. The Section Rooms and the approaches thereto shall not be used for any notices, exhibitions, or other purposes than those of the Association

SECTIONAL COMMITTEES

4 The work of each Section shall be conducted by a Sectional Committee, which shall consist of the following :—

Constitution

(i) The Officers of the Section during their term of office.
(ii) All past Presidents of that Section.
(iii) Such other Members of the Association, present at any Annual Meeting, as the Sectional Committee, thus constituted, may co-opt for the period of the meeting :

Provided always that—

Privilege of Old Members.

(*a*) Any Member of the Association who has served on the Committee of any Section in any previous year, and who has intimated his intention of being present at the Annual Meeting, is eligible as a member of that Committee at their first meeting

Daily Co-optation

(*b*) A Sectional Committee may co-opt members, as above set forth, at any time during the Annual Meeting, and shall publish daily a revised list of the members.

(c) A Sectional Committee may, at any time during the Annual Meeting, appoint not more than three persons present at the meeting to be Vice-Presidents of the Section, in addition to those previously appointed by the Council. Additional Vice-Presidents.

5. The chief executive officers of a Section shall be the President and the Recorder. They shall have power to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the Sectional Committee, and they shall report such action to the Sectional Committee at its next meeting. EXECUTIVE FUNCTIONS

The President (or, in his absence, one of the Vice-Presidents) shall preside at all meetings of the Sectional Committee or of the Section. His ruling shall be absolute on all points of order that may arise. Of President

The Recorder shall be responsible for the punctual transmission to the Assistant Secretary of the daily programme of his Section, of the recommendations adopted by the Sectional Committee, of the printed returns, abstracts, reports, or papers appertaining to the proceedings of his Section at the Annual Meeting, and for the correspondence and minutes of the Sectional Committee. And of Recorder.

6. The Sectional Committee shall nominate, before the close of the Annual Meeting, not more than six of its own members to be members of an Organising Committee, with the officers to be subsequently appointed by the Council, and past Presidents of the Section, from the close of the Annual Meeting until the conclusion of its meeting on the first day of the ensuing Annual Meeting. Organising Committee

Each Organising Committee shall hold such Meetings as are deemed necessary by its President for the organisation of the ensuing Sectional proceedings, and shall hold a meeting on the first Wednesday of the Annual Meeting. to nominate members of the Sectional Committee, to confirm the Provisional Programme of the Section, and to report to the Sectional Committee.

Each Sectional Committee shall meet daily, unless otherwise determined, during the Annual Meeting: to co-opt members, to complete the arrangements for the next day, and to take into consideration any suggestion for the advancement of Science that may be offered by a member, or may arise out of the proceedings of the Section. Sectional Committee.

No paper shall be read in any Section until it has been accepted by the Sectional Committee and entered as accepted on its Minutes. Papers and Reports.

Any report or paper read in any one Section may be read also in any other Section.

No paper or abstract of a paper shall be printed in the Annual Report of the Association unless the manuscript has been received by the Recorder of the Section before the close of the Annual Meeting.

Recommendations. It shall be within the competence of the Sectional Committee to review the recommendations adopted at preceding Annual Meetings, as published in the Annual Reports of the Association, and the communications made to the Section at its current meetings, for the purpose of selecting definite objects of research, in the promotion of which individual or concerted action may be usefully employed, and, further, to take into consideration those branches or aspects of knowledge on the state and progress of which reports are required to make recommendations and nominate individuals or Research Committees to whom the preparation of such reports, or the task of research, may be entrusted, discriminating as to whether, and in what respects, these objects may be usefully advanced by the appropriation of money from the funds of the Association, whether by reference to local authorities, public institutions, or Departments of His Majesty's Government. The appointment of such Research Committees shall be made in accordance with the provisions of Chapter IV

No proposal arising out of the proceedings of any Section shall be referred to the Committee of Recommendations unless it shall have received the sanction of the Sectional Committee

Publication. 7. Papers ordered to be printed *in extenso* shall not be included in the Annual Report, if published elsewhere prior to the issue of the Annual Report in volume form. Reports of Research Committees shall not be published elsewhere than in the Annual Report without the express sanction of the Council.

Copyright. 8. The copyright of papers ordered by the General Committee to be printed *in extenso* in the Annual Report shall be vested in the authors, and the copyright of the reports of Research Committees appointed by the General Committee shall be vested in the Association

Chapter X.

Admission of Members and Associates.

1. No technical qualification shall be required on the part of an applicant for admission as a Member or as an Associate of the British Association, but the Council is empowered, in the event of special circumstances arising, to impose suitable conditions and restrictions in this respect. Applications.

* Every person admitted as a Member or an Associate shall conform to the Rules and Regulations of the Association, any infringement of which on his part may render him liable to exclusion by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any Annual Meeting or to cancel a ticket of admission already issued. Obligations.

It shall be competent for the General Officers to act, in the name of the Council, on any occasion of urgency which cannot be brought under the consideration of the Council, and they shall report such action to the Council at the next Meeting.

2. All Members are eligible to any office in the Association. Conditions and Privileges of Membership.

(i) Every *Life Member* shall pay, on admission, the sum of Ten Pounds.

Life Members shall receive *gratis* the Annual Reports of the Association.

(ii) Every *Annual Member* shall pay, on admission, the sum of Two Pounds, and in any subsequent year the sum of One Pound.

Annual Members shall receive *gratis* the Report of the Association for the year of their admission and for the years in which they continue to pay, *without intermission*, their annual subscription. An Annual Member who omits to subscribe for any particular year shall lose for that and all future years the privilege of receiving the Annual Reports of the Association *gratis*. He, however, may resume his other privileges as a Member at any subsequent Annual Meeting by paying on each such occasion the sum of One Pound.

(iii) Every *Associate* for a year shall pay, on admission, the sum of One Pound.

* Amended by the General Committee at Dublin, 1908.

Associates shall not receive the Annual Report gratuitously. They shall not be eligible to serve on any Committee, nor be qualified to hold any office in the Association.

(iv) *Ladies* may become Members or Associates on the same terms as gentlemen, or can obtain a *Lady's Ticket* (transferable to ladies only) on the payment of One Pound

Corresponding Members

3. Corresponding Members may be appointed by the General Committee, on the nomination of the Council. They shall be entitled to all the privileges of Membership

Annual Subscriptions

4 Subscriptions are payable at or before the Annual Meeting Annual Members not attending the meeting may make payment at any time before the close of the financial year on June 30 of the following year.

The Annual Report

5 The Annual Report of the Association shall be forwarded *gratis* to individuals and institutions entitled to receive it.

Annual Members whose subscriptions have been intermitted shall be entitled to purchase the Annual Report at two-thirds of the publication price, and Associates for a year shall be entitled to purchase, at the same price, the volume for that year

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Chapter XI

Corresponding Societies Conference of Delegates.

Corresponding Societies are constituted as follows

Affiliated Societies

1. (i) Any Society which undertakes local scientific investigation and publishes the results may become a Society *affiliated* to the British Association.

Each Affiliated Society may appoint a Delegate, who must be or become a Member of the Association and must attend the meetings of the Conference of Delegates. He shall be *ex officio* a Member of the General Committee.

Associated Societies

(ii) Any Society formed for the purpose of encouraging the study of Science, which has existed for three years and numbers not fewer than fifty members, may become a Society *associated* with the British Association.

Each Associated Society shall have the right to appoint a Delegate to attend the Annual Conference. Such Delegates must be or become either Members or Associates of the British Association, and shall have all the rights of Delegates appointed by the Affiliated Societies, except that of membership of the General Committee.

2. Application may be made by any Society to be placed on the list of Corresponding Societies Such application must be addressed to the Assistant Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended it should be considered, and must, in the case of Societies desiring to be affiliated, be accompanied by specimens of the publications of the results of local scientific investigations recently undertaken by the Society — Applications

3 A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee, for the purpose of keeping themselves generally informed of the work of the Corresponding Societies and of superintending the preparation of a list of the papers published by the Affiliated Societies This Committee shall make an Annual Report to the Council, and shall suggest such additions or changes in the list of Corresponding Societies as they may consider desirable — CORRESPONDING SOCIETIES COMMITTEE.

Procedure.

(i) Each Corresponding Society shall forward every year to the Assistant Secretary of the Association, on or before June 1, such particulars in regard to the Society as may be required for the information of the Corresponding Societies Committee

(ii) There shall be inserted in the Annual Report of the Association a list of the papers published by the Corresponding Societies during the preceding twelve months which contain the results of local scientific work conducted by them—those papers only being included which refer to subjects coming under the cognisance of one or other of the several Sections of the Association

4. The Delegates of Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairman, and Secretary or Secretaries shall be nominated annually by the Council and appointed by the General Committee. The members of the Corresponding Societies Committee shall be *ex officio* members of the Conference — CONFERENCE OF DELEGATES.

Procedure and Functions.

(i) The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during

each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the discussions.

(ii) The Conference of Delegates shall be empowered to submit Resolutions to the Committee of Recommendations for their consideration, and for report to the General Committee.

(iii) The Sectional Committees of the Association shall be requested to transmit to the Secretaries of the Conference of Delegates copies of any recommendations to be made to the General Committee bearing on matters in which the co-operation of Corresponding Societies is desirable It shall be competent for the Secretaries of the Conference of Delegates to invite the authors of such recommendations to attend the meetings of the Conference in order to give verbal explanations of their objects and of the precise way in which they desire these to be carried into effect

(iv) It shall be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they may be able to bring such recommendations adequately before their respective Societies

(v) The Conference may also discuss propositions regarding the promotion of more systematic observation and plans of operation, and of greater uniformity in the method of publishing results

Chapter XII.

Amendments and New Rules

Alterations

Any alterations in the Rules, and any amendments or new Rules that may be proposed by the Council or individual Members, shall be notified to the General Committee on the first day of the Annual Meeting, and referred forthwith to the Committee of Recommendations, and, on the report of that Committee, shall be submitted for approval at the last meeting of the General Committee.

TRUSTEES AND GENERAL OFFICERS, 1831–1912.

TRUSTEES.

1832–70 (Sir) R I. Murchison (Bart), F R.S.
1832–62 John Taylor, Esq, F R S
1832–39 C Babbage, Esq, F.R S
1839–44 F Baily, Esq, F.R S.
1844–58 Rev G Peacock, F R S
1858–82 General E Sabine, F R.S.
1862–81 Sir P Egerton, Bart., F R S
1872– Sir J Lubbock, Bart (now Lord Avebury), F R S.
1881–83 W. Spottiswoode, Esq, Pres R S
1883– Lord Rayleigh, F R S
1883–98 Sir Lyon (afterwards Lord) Playfair, F.R S
1898– Prof. (Sir) A W Rucker, F R S

GENERAL TREASURERS

1831 Jonathan Gray, Esq
1832–62 John Taylor, Esq, F R S
1862–74 W. Spottiswoode, Esq, F.R S.
1874–91 Prof A W Williamson, F.R S.
1891–98 Prof (Sir) A W Rucker, F R S
1898–1904 Prof G C Foster, F R S.
1904– Prof John Perry, F R.S

GENERAL SECRETARIES.

1832–35 Rev W Vernon Harcourt, F R S
1835–36 Rev W Vernon Harcourt, F R S, and F. Baily, Esq, F R S
1836–37 Rev W Vernon Harcourt, F R S, and R I Murchison, Esq, F R S
1837–39 R. I Murchison, Esq, F.R S, and Rev G Peacock, F R S
1839–45 Sir R I Murchison, F R S, and Major E Sabine, F R S
1845–50 Lieut-Colonel E Sabine, F R S.
1850–52 General E Sabine, F R S, and J F Royle, Esq, F R.S
1852–53 J F Royle, Esq, F.R S
1853–59 General E Sabine, F R S.
1859–61 Prof. R Walker, F R S
1861–62 W Hopkins, Esq, F R S.
1862–63 W Hopkins, Esq, F R S, and Prof J Phillips, F R S.
1863–65 W Hopkins, Esq, F R S, and F Galton, Esq, F R S.
1865–66 F Galton, Esq, F R S
1866–68 F Galton, Esq, F R S, and Dr. T A Hirst, F.R S
1868–71 Dr T. A Hirst, F R S, and Dr. T Thomson, F R S
1871–72 Dr T. Thomson, F R.S, and Capt Douglas Galton, F R S.
1872–76 Capt D. Galton, F R S, and Dr. Michael Foster, F R S
1876–81 Capt D Galton, F R S, and Dr P L Sclater, F R S
1881–82 Capt D Galton, F R S, and Prof F M Balfour, F R S
1882–83 Capt Douglas Galton, F R S
1883–95 Sir Douglas Galton, F R S and A G Vernon Harcourt, Esq, F R S
1895–97 A G Vernon Harcourt, Esq, F R S, and Prof E A Schafer, F R S
1897–1900 Prof Schafer, F R S, and Sir W C. Roberts-Austen, F R S.
1900–02 Sir W C Roberts-Austen, F R S, and Dr D H Scott, F R S
1902–03 Dr D H. Scott, F R S, and Major P A MacMahon, F R S
1903– Major P A MacMahon, F R S, and Prof W A Herdman, F R S

ASSISTANT GENERAL SECRETARIES, &c 1831–1904

1831 John Phillips, Esq, *Secretary*
1832 Prof J D. Forbes, *Acting Secretary.*
1832–62 Prof. John Phillips, F R S
1862–78 G Griffith, Esq, M A.
1881 G. Griffith, Esq, M A, *Acting Secretary.*
1881–85 Prof T G Bonney, F R S, *Secretary*
1885–90 A T. Atchison, Esq, M A, *Secretary*
1890 G Griffith, Esq, M A, *Acting Secretary.*
1890–1902 G. Griffith, Esq, M.A
1902–04 J. G. Garson, Esq, M D

ASSISTANT SECRETARIES.

1878–80 J E H Gordon, Esq, B A
1904–09 A. Silva White, Esq
1909– O J R Howarth, Esq, M A

Presidents and Secretaries of the Sections of the Association, 1901–1912.

Date and Place	Presidents	Secretaries
	SECTION A.[1]—MATHEMATICS AND PHYSICS.	
1901. Glasgow ...	Major P A MacMahon, F R S —*Dep of Astronomy*, Prof H H Turner, F R S	H S Carslaw, C H Lees, W Stewart, Prof L R Wilberforce.
1902 Belfast .	Prof J Purser, LL D, M R I A —*Dep of Astronomy*, Prof A Schuster, F R S	H. S. Carslaw, A. R. Hinks, A. Larmor, C H. Lees, Prof. W. B. Morton, A. W Porter.
1903 Southport	C. Vernon Boys, F R S —*Dep of Astronomy and Meteorology*, Dr W N Shaw, F R S	D E Benson, A R Hinks, R W H T Hudson, Dr C H Lees, J Loton, A W Porter
1904. Cambridge	Prof H Lamb, F R S —*Sub-Section of Astronomy and Cosmical Physics*, Sir J Eliot, K C I E, F.R S	A R Hinks, R W H T Hudson, Dr. C H Lees, Dr W. J S. Lockyer, A W Porter, W. C D Whetham
1905 SouthAfrica	Prof A R. Forsyth, M A, F R S	A R Hinks, S S Hough, R T A Innes, J H Jeans, Dr C H. Lees
1906. York	Principal E H. Griffiths, F R S	Dr L N G Filon, Dr J. A Harker, A R Hinks, Prof A W Porter, H Dennis Taylor
1907. Leicester. .	Prof A E H Love, M A, F R S	E E Brooks, Dr L N G Filon, Dr J A Harker, A R Hinks, Prof A W Porter.
1908 Dublin	Dr W N Shaw, F.R S	Dr W G Duffield, Dr L N G Filon, E Gold, Prof. J A, McClelland, Prof A. W Porter, Prof E T Whittaker.
1909 Winnipeg	Prof E Rutherford, F R S	Prof. F Allen, Prof. J. C Fields, E Gold, F Horton, Prof A W Porter, Dr A A Rambaut.
1910. Sheffield	Prof E W Hobson, F R.S	H Bateman, A S Eddington, E Gold, Dr F Horton, Dr S R Milner, Prof A W Porter
1911. Portsmouth	Prof H H Turner, F R S .	H Bateman, Prof P V Bevan, A S Eddington, E Gold, Prof A. W Porter, P A Yapp
1912 Dundee ..	Prof H L. Callendar, F.R S	Prof P. V Bevan, E Gold, Dr H B Heywood, R Norrie, Prof A. W. Porter, W. G Robson, F J M. Stratton

SECTION B.[2]—CHEMISTRY

1901. Glasgow ..	Prof Percy F. Frankland, F R S	W. C. Anderson, G G Henderson, W J Pope, T K Rose
1902. Belfast. .. .	Prof. E. Divers, F.R.S	R. F. Blake, M. O. Forster, Prof G. G. Henderson, Prof. W. J Pope.
1903. Southport	Prof W. N. Hartley, D.Sc, F R S	Dr M O. Forster, Prof G G Henderson, J Ohm, Prof W J Pope

[1] Section A was constituted under this title in 1835, when the sectional division was introduced. The previous division was into 'Committees of Sciences'

[2] 'Chemistry and Mineralogy,' 1835–1894.

Date and Place	Presidents	Secretaries
1904. Cambridge	Prof Sydney Young, F.R.S ...	Dr. M. O Forster, Prof. G G. Henderson, Dr. H O Jones, Prof. W. J Pope
1905 SouthAfrica	George T Beilby	W. A Caldecott, Dr. M O Forster, Prof G G. Henderson, C F Juritz.
1906. York	Prof Wyndham R Dunstan, F R S	Dr. E F Armstrong, Prof A W Crossley, S H Davies, Prof W J. Pope.
1907. Leicester ..	Prof A. Smithells, F R S. .	Dr E F Armstrong, Prof A W Crossley, J. H. Hawthorn, Dr F M Perkin
1908 Dublin .	Prof F. S Kipping, F R S	Dr E F Armstrong, Dr A McKenzie, Dr F M Perkin, Dr J H Pollock
1909 Winnipeg	Prof H E Armstrong, F R S	Dr E F Armstrong, Dr T. M Lowry, Dr F M Perkin, J W Shipley
1910. Sheffield	J E Stead, F R S	Dr E F Armstrong, Dr T M. Lowry, Dr. F. M Perkin, W E S. Turner
	Sub section of Agriculture, A D Hall, F R S	Dr C. Crowther, J Golding, Dr. E. J Russell
1911 Portsmouth	Prof J Walker, F R S	Dr E F Armstrong, Dr C H Desch, Dr T M Lowry, Dr F. Beddow
1912 Dundee .	Prof A Senier, M D	Dr E F Armstrong, Dr C. H Desch, Dr A Holt, Dr J K Wood

SECTION C[3] - GEOLOGY

Date and Place	Presidents	Secretaries
1901 Glasgow	John Horne, F R S .	H L Bowman, H W Monckton
1902 Belfast	Lieut -Gen C. A McMahon, F.R.S.	H L. Bowman, H. W. Monckton, J. St J Phillips, H. J. Seymour
1903 Southport	Prof W W Watts, M A, M Sc	H L Bowman, Rev W L Carter, J Lomas, H W. Monckton
1904. Cambridge	Aubrey Strahan, F.R.S	H L Bowman, Rev W. L Carter, J Lomas, H Woods
1905. SouthAfrica	Prof H A Miers, M A, D Sc, F R S	H L Bowman, J Lomas, Dr Molengraaff, Prof A Young, Prof. R B. Young
1906 York	G. W Lamplugh, F R S .	H L Bowman, Rev W L Carter, Rev W Johnson, J Lomas
1907 Leicester ...	Prof J. W Gregory, F R S	Dr F W Bennett, Rev W L. Carter, Prof T Groom, J Lomas
1908. Dublin .	Prof John Joly, F R S	Rev W. L Carter, J Lomas, Prof S H Reynolds, H J Seymour
1909 Winnipeg	Dr A Smith Woodward, F R S	W L Carter, Dr A R Dwerryhouse, R T Hodgson, Prof S H Reynolds.
1910 Sheffield	Prof A P Coleman, F R S	W L Carter, Dr A R Dwerryhouse, B Hobson, Prof S H Reynolds
1911 Portsmouth	A Harker, F R S	Col C W Bevis, W L Carter, Dr A R Dwerryhouse, Prof S H Reynolds
1912 Dundee ..	Dr. B N Peach, F.R S. .	Prof W B. Boulton, A W R Don, Dr A R Dwerryhouse, Prof S H. Reynolds

[3] 'Geology and Geography,' 1835-1850

SECTION D.[4]—ZOOLOGY.

Date and Place	Presidents	Secretaries
1901 Glasgow ..	Prof J. Cossar Ewart, F R S.	J G Kerr, J Rankin, J Y Simpson.
1902 Belfast ..	Prof G B Howes, F R.S. ...	Prof. J G Kerr, R. Patterson, J Y Simpson
1903 Southport	Prof. S J. Hickson, F R S.	Dr J H Ashworth, J Barcroft, A Quayle, Dr J Y Simpson, Dr H W. M Tims
1904. Cambridge	William Bateson, F R S . .	Dr. J. H. Ashworth, L Doncaster, Prof J. Y Simpson, Dr H W M Tims
1905 SouthAfrica	G A Boulenger, F.R S	Dr Pakes, Dr. Purcell, Dr H. W M Tims, Prof J Y Simpson
1906 York .. .	J. J Lister, F.R S	Dr J. H Ashworth, L Doncaster, Oxley Grabham, Dr H W. M Tims.
1907 Leicester ..	Dr W E Hoyle, M A	Dr J H Ashworth, L Doncaster E E Lowe, Dr H W M Tims
1908 Dublin	Dr S F Harmer, F R S .	Dr J H Ashworth, L Doncaster, Prof A Fraser, Dr. H W M Tims
1909 Winnipeg .	Dr A E Shipley, F.R S .	C. A Baragar, C L Boulenger, Dr J Pearson, Dr H W M Tims
1910 Sheffield	Prof G C Bourne, F.R S .	Dr J H. Ashworth, L Doncaster, T J Evans, Dr H W M Tims
1911 Portsmouth	Prof D'Arcy W Thompson, C B	Dr. J H Ashworth, C Foran, R D Laurie, Dr H W M Tims
1912 Dundee	Dr P Chalmers Mitchell, F R S	Dr J H. Ashworth, R D. Laurie, Miss D L Mackinnon, Dr H W M Tims

SECTION E.[5]—GEOGRAPHY.

Date and Place	Presidents	Secretaries
1901 Glasgow	Dr H R Mill, F R.G S. ...	H N. Dickson, E Heawood, G Sandeman, A C Turner
1902 Belfast.. ...	Sir T H. Holdich, K C B. ..	G. G Chisholm, E Heawood, Dr A J Herbertson, Dr J A Lindsay
1903 Southport .	Capt E W Creak, R.N , C B , F R S	E. Heawood, Dr A J Herbertson, E A Reeves, Capt J C Underwood
1904. Cambridge	Douglas W. Freshfield	E Heawood, Dr A J Herbertson, H Y Oldham, E A Reeves
1905 SouthAfrica	Adm Sir W J L Wharton, R N , K C.B , F R S.	A H. Cornish-Bowden, F Flowers, Dr A J Herbertson, H Y Oldham
1906 York. .	Rt Hon Sir George Goldie, K C.M G , F R S	E. Heawood, Dr A. J Herbertson, E A. Reeves, G Yeld
1907. Leicester ..	George G Chisholm, M.A.	E Heawood, O J R Howarth, E A Reeves, T Walker
1908 Dublin .	Major E H Hills, C.M G., R.E	W F Bailey, W. J Barton, O J R. Howarth, E. A. Reeves

[4] 'Zoology and Botany,' 1835–1847; 'Zoology and Botany, including Physiology,' 1848–1865, 'Biology,' 1866–1894

[5] Section E was that of 'Anatomy and Medicine,' 1835–1840, of 'Physiology' (afterwards incorporated in Section D), 1841–1847 It was assigned to 'Geography and Ethnology,' 1851–1868; 'Geography,' 1869.

Date and Place	Presidents	Secretaries
1909 Winnipeg..	Col Sir D Johnston, K C M G, C B, R E	G G. Chisholm, J. McFarlane, A McIntyre
1910 Sheffield	Prof A J Herbertson, M A, Ph D	Rev W J. Barton, Dr R. Brown, J. McFarlane, E A Reeves
1911 Portsmouth	Col C F Close, R E, C M G	J McFarlane, E A Reeves, W P Smith
1912 Dundee ..	Col Sir C M Watson, K.C M G	Rev W J. Barton, J McFarlane, E A Reeves, D Wylie

SECTION F[6]—ECONOMIC SCIENCE AND STATISTICS.

1901 Glasgow	Sir R Giffen, K C.B, F.R S	W W Blackie, A L Bowley, E Cannan, S J Chapman
1902 Belfast .	E Cannan, M A, LL D ..	A L Bowley, Prof. S J Chapman, Dr A Duffin
1903 Southport	E W Brabrook, C.B	A L. Bowley, Prof S J Chapman, Dr B W Ginsburg, G Lloyd
1904 Cambridge	Prof Wm Smart, LL D. .	J. E Bidwell, A L Bowley, Prof S J Chapman, Dr B W Ginsburg
1905. SouthAfrica	Rev W Cunningham, D D., D Sc	R A Ababrelton, A L Bowley, Prof. H E S Fremantle, H O Meredith
1906 York... .	A L Bowley, M A.	Prof S. J Chapman, D H Macgregor, H O Meredith, B S Rowntree.
1907. Leicester	Prof W. J Ashley, M A	Prof S J Chapman, D H. Macgregor, H O Meredith, T. S. Taylor
1908 Dublin	W M Acworth, M A. . .	W G S. Adams, Prof S J Chapman, Prof D H. Macgregor, H O Meredith
	Sub-section of Agriculture—Rt Hon Sir H. Plunkett	A D Hall, Prof J Percival, J H Priestley, Prof J Wilson
1909 Winnipeg	Prof S J Chapman, M A ..	Prof A B Clark, Dr W A Manahan, Dr W R Scott
1910 Sheffield	Sir H Llewellyn Smith, K C B, M A	C R Fay, H O. Meredith, Dr W R Scott, R Wilson
1911 Portsmouth	Hon W. Pember Reeves .	C R Fay, Dr. W R Scott, H A. Stibbs
1912 Dundee .	Sir H. H. Cunynghame, K C B	C R Fay, Dr W R Scott, E Tosh

SECTION G[7]—ENGINEERING.

1901 Glasgow	R E Crompton, M.Inst C E.	H Bamford, W E Dalby, W A Price.
1902. Belfast	Prof J Perry, F R S ...	M Barr, W A Price, J Wylie
1903. Southport	C Hawksley, M Inst C E. .	Prof W E Dalby, W T Maccall, W A Price
1904 Cambridge	Hon C A Parsons, F R S	J B Peace, W T Maccall, W. A Price.
1905 SouthAfrica	Col Sir C Scott-Moncrieff, G.C S I, K C M G, R E	W T Maccall, W B Marshall, Prof. H Payne, E Williams
1906 York .	J A Ewing, F R S ...	W T Maccall, W A Price, J Triffit
1907 Leicester ..	Prof Silvanus P Thompson, F R S	Prof. E G Coker, A C. Harris, W A Price, H E Wimperis
1908 Dublin....	Dugald Clerk, F R S.	Prof E G Coker, Dr. W E Lilly, W A Price, H E. Wimperis.

[6] 'Statistics,' 1835–1855
[7] 'Mechanical Science,' 1836–1900

Date and Place	Presidents	Secretaries
1909. Winnipeg	Sir W H White, K.C.B., F.R.S.	E E Brydone-Jack, Prof E G Coker, Prof E W Marchant, W A Price
1910 Sheffield ..	Prof. W E Dalby, M.A., M.Inst.C.E.	F. Boulden, Prof E G. Coker, A A Rowse, H E Wimperis
1911. Portsmouth	Prof. J H Biles, LL.D., D.Sc.	H Ashley, Prof E G. Coker, A. A Rowse, H E Wimperis
1912 Dundee ..	Prof A Barr, D.Sc.	Prof E G Coker, A R Fulton, H Richardson, A A. Rowse, H. E Wimperis.

SECTION H [8]—ANTHROPOLOGY

1901 Glasgow ...	Prof D J. Cunningham, F.R.S.	W Crooke, Prof A F Dixon, J F Gemmill, J L Myres
1902 Belfast .	Dr A C. Haddon, F.R.S.	R. Campbell, Prof A F Dixon J L Myres
1903. Southport	Prof J Symington, F.R.S. .	E N Fallaize, H S Kingsford, E M Littler, J L Myres
1904. Cambridge	H Balfour, M.A.	W L H Duckworth, E N Fallaize, H. S Kingsford, J L Myres
1905 SouthAfrica	Dr A C Haddon, F.R.S. ..	A R Brown, A von Dessauer, E S Hartland
1906. York .	E Sidney Hartland, F.S.A.	Dr G A Auden, E N Fallaize, H S Kingsford, Dr F C Shrubsall
1907 Leicester	D G Hogarth, M.A.	C. J Billson, E N Fallaize, H S Kingsford, Dr F C Shrubsall
1908. Dublin . ..	Prof W. Ridgeway, M.A.	E N Fallaize, H S Kingsford, Dr. F C Shrubsall, L E Steele
1909 Winnipeg	Prof J L Myres, M.A. ...	H S Kingsford, Prof C J Patten, Dr F C Shrubsall
1910. Sheffield	W Crooke, B.A.	E N Fallaize, H S Kingsford, Prof C J Patten, Dr F C Shrubsall
1911. Portsmouth	W H R Rivers, M.D., F.R.S.	E N Fallaize, H S Kingsford, E W. Martindell, H Rundle, Dr F C Shrubsall
1912 Dundee .	Prof G. Elliot Smith, F.R.S.	D D Craig, E N Fallaize, E W. Martindell, Dr F C Shrubsall

SECTION I.[9]—PHYSIOLOGY (including EXPERIMENTAL PATHOLOGY AND EXPERIMENTAL PSYCHOLOGY)

1901 Glasgow ...	Prof J. G. McKendrick, F.R.S.	W B Brodie, W. A. Osborne, Prof W H. Thompson
1902. Belfast . .	Prof W D. Halliburton, F.R.S.	J. Barcroft, Dr W A Osborne, Dr C Shaw
1904 Cambridge	Prof C. S Sherrington, F.R.S.	J Barcroft, Prof T G Brodie, Dr L E Shore
1905 SouthAfrica	Col D. Bruce, C.B., F.R.S. ...	J Barcroft, Dr Baumann, Dr. Mackenzie, Dr G W Robertson, Dr Stanwell
1906. York	Prof F Gotch, F.R.S.	J. Barcroft, Dr. J M Hamill, Prof J S Macdonald, Dr. D S. Long

[8] Established 1884
[9] Established 1894

Date and Place	Presidents	Secretaries
1907. Leicester..	Dr. A. D Waller, F R S	Dr N H Alcock, J. Barcroft, Prof. J S Macdonald, Dr. A Warner
1908. Dublin... .	Dr J. Scott Haldane, F R S	Prof D J Coffey, Dr P T. Herring, Prof J S Macdonald, Dr H E Roaf.
1909 Winnipeg...	Prof. E H. Starling, F R S ...	Dr N H. Alcock, Prof P T Herring, Dr W Webster.
1910. Sheffield ...	Prof A B. Macallum, F R S	Dr H G M Henry, Keith Lucas, Dr H E Roaf, Dr. J Tait
1911 Portsmouth	Prof J S Macdonald, B A	Dr J T Leon, Dr Keith Lucas, Dr H E. Roaf, Dr J Tait
1912 Dundee .	Leonard Hill, F R S ..	Dr Keith Lucas, W Moodie, Dr. H E Roaf, Dr J Tait

SECTION K.[10]—BOTANY.

1901 Glasgow ..	Prof I B Balfour, F R S ..	D T Gwynne-Vaughan, G F Scott-Elliot, A C Seward, H Wager
1902 Belfast .	Prof J R Green, F R S .	A G Tansley, Rev C H Waddell, H Wager, R H Yapp
1903 Southport	A C Seward, F R.S ..	H. Ball, A G Tansley, H Wager, R H Yapp
1904 Cambridge	Francis Darwin, F.R S . *Sub-section of Agriculture*—Dr W Somerville	Dr F F Blackman, A G Tansley, H Wager, T B Wood, R H Yapp
1905 SouthAfrica	Harold Wager, F R S	R P Gregory, Dr Marloth, Prof Pearson, Prof R H Yapp
1906 York	Prof F. W Oliver, F R S	Dr A Burtt, R P Gregory, Prof A G Tansley, Prof R H Yapp
1907 Leicester	Prof. J B Farmer, F R S .	W. Bell, R. P. Gregory, Prof A G Tansley, Prof R H Yapp
1908. Dublin .	Dr F F. Blackman, F R S	Prof H. H Dixon, R P Gregory, A G Tansley, Prof R H Yapp
1909. Winnipeg	Lieut Col D Prain, C I E, F R S	Prof A H R Buller, Prof D T Gwynne-Vaughan, Prof R H Yapp
	Sub-section of Agriculture—Major P G Craigie, C B	W J Black, Dr E J. Russell, Prof J Wilson
1910. Sheffield	Prof J W H Trail, F R S	B H Bentley, R P Gregory, Prof D T Gwynne-Vaughan, Prof R H Yapp
1911 Portsmouth	Prof F E Weiss, D Sc .	C G Delahunt, Prof D T Gwynne-Vaughan, Dr. C E Moss, Prof R H Yapp
	Sub-section of Agriculture—W Bateson, M A, F R S	J Golding, H R Pink, Dr E J. Russell
1912 Dundee ..	Prof F Keeble, D Sc .	J Brebner, Prof D. T Gwynne-Vaughan, Dr C E Moss, D. Thoday.

SECTION L.—EDUCATIONAL SCIENCE.

1901 Glasgow .	Sir John E. Gorst, F R S .	R A Gregory, W. M Heller, R Y. Howie, C. W Kimmins, Prof H L Withers
1902 Belfast ..	Prof H E. Armstrong, F R S	Prof R A. Gregory, W M Heller R M Jones, Dr C W Kimmins Prof H L Withers

[10] Established 1895

Date and Place	Presidents	Secretaries
1903 Southport	Sir W. de W. Abney, K C.B , F.R S	Prof. R A Gregory, W M Heller, Dr C W. Kimmins, Dr H L Snape
1904. Cambridge	Bishop of Hereford, D D ..	J H Flather, Prof R A Gregory, W M Heller, Dr C W Kimmins.
1905 SouthAfrica	Prof Sir R C Jebb, D C L , M.P	A D Hall, Prof Hele-Shaw, Dr C W. Kimmins, J R Whitton
1906 York	Prof. M E Sadler, LL D .	Prof R A Gregory, W M Heller, Hugh Richardson
1907. Leicester .	Sir Philip Magnus, M.P	W. D Eggar, Prof R A. Gregory, J S Laver, Hugh Richardson.
1908 Dublin	Prof L C Miall, F R S	Prof E P Culverwell, W D Eggar, George Fletcher, Prof R A Gregory, Hugh Richardson
1909 Winnipeg. .	Rev H B Gray, D D .	W D Eggar, R Fletcher, J L Holland, Hugh Richardson
1910 Sheffield	Principal H A Miers, F R S	A J Arnold, W D Eggar, J L Holland, Hugh Richardson.
1911 Portsmouth	Rt Rev. J E C Welldon, D D.	W D. Eggar, O Freeman, J L Holland, Hugh Richardson
1912 Dundee .	Prof J Adams, M A ...	D Berridge, Dr J Davidson, Prof J A Green, Hugh Richardson

SECTION M —AGRICULTURE.

1912 Dundee .	T H Middleton, M A ...	Dr C Crowther, J Golding, Dr A Lauder, Dr E J Russell

CHAIRMEN AND SECRETARIES OF THE CONFERENCES OF DELEGATES OF CORRESPONDING SOCIETIES, 1901-12.*

Date and Place	Chairmen	Secretaries
1901 Glasgow	F W. Rudler, F G.S	Dr. J G Garson, A Somerville
1902 Belfast	Prof W W. Watts, F G S	E J Bles
1903 Southport	W. Whitaker, F R S. .	F W Rudler
1904 Cambridge	Prof E H Griffiths, F R S	F W Rudler
1905 London	Dr A Smith Woodward, F R S	F W Rudler.
1906 York .	Sir Edward Brabrook, C B ...	F W Rudler
1907 Leicester	H J Mackinder, M A	F W. Rudler, I S O
1908 Dublin .	Prof. H A Miers, F R S .	W P D Stebbing
1909 London .	Dr A C Haddon, F R S	W P. D. Stebbing
1910 Sheffield . .	Dr Tempest Anderson .	W P D Stebbing
1911 Portsmouth	Prof J. W Gregory, F R S .	W P D Stebbing.
1912 Dundee .	Prof F. O Bower, F R S.	W P D Stebbing

EVENING DISCOURSES, 1901-1912.

Date and Place	Lecturer	Subject of Discourse
1901 Glasgow .	Prof W Ramsay, F R S	The Inert Constituents of the Atmosphere.
	Francis Darwin, F R S ..	The Movements of Plants
1902 Belfast ..	Prof J J Thomson, F R S	Becquerel Rays and Radio-activity
	Prof W F R Weldon, F R S	Inheritance.
1903 Southport .	Dr R Munro	Man as Artist and Sportsman in the Palæolithic Period
	Dr A Rowe .	The Old Chalk Sea, and some of its Teachings
1904 Cambridge	Prof G H Darwin, F R S ..	Ripple Marks and Sand-Dunes
	Prof. H F Osborn ..	Palæontological Discoveries in the Rocky Mountains
1905 South Africa		
Cape Town . .	Prof E B. Poulton, F R S. .	W J Burchell's Discoveries in South Africa
	C Vernon Boys, F R S	Some Surface Actions of Fluids
Durban .	Douglas W Freshfield	The Mountains of the Old World
	Prof W A Herdman, F R S	Marine Biology
Pietermaritzburg	Col D Bruce, C B , F R S	Sleeping Sickness
	H T Ferrar	The Cruise of the 'Discovery'
Johannesburg	Prof W E Ayrton, F R S	The Distribution of Power
	Prof. J O Arnold....	Steel as an Igneous Rock
Pretoria	A E Shipley, F R S	Fly-borne Diseases Malaria, Sleeping Sickness, &c
Bloemfontein	A R Hinks	The Milky Way and the Clouds of Magellan
Kimberley	Sir Wm Crookes, F R S .	Diamonds
	Prof J B Porter .	The Bearing of Engineering on Mining
Bulawayo .	D Randall-MacIver . .	The Ruins of Rhodesia

* Established 1885.

Date and Place	Lecturer	Subject of Discourse
1906 York	Dr. Tempest Anderson	Volcanoes
	Dr A D. Waller, F.R S	The Electrical Signs of Life, and their Abolition by Chloroform
1907. Leicester ...	W. Duddell, F R.S ...	The Ark and the Spark in Radio-telegraphy.
	Dr F A Dixey	Recent Developments in the Theory of Mimicry
1908. Dublin ..	Prof H H Turner, F R S	Halley's Comet
	Prof W M Davis	The Lessons of the Colorado Canyon
1909 Winnipeg ..	Dr A E H Tutton, F R S	The Seven Styles of Crystal Architecture
	Prof W A Herdman, F R S	Our Food from the Waters
	[1] Prof H B Dixon, F R S ..	The Chemistry of Flame
	[1] Prof J H Poynting, F R S	The Pressure of Light
1910 Sheffield .	Prof W Stirling, M D	Types of Animal Movement [2]
	D G Hogarth .	New Discoveries about the Hittites
1911. Portsmouth	Dr Leonard Hill, F R S	The Physiology of Submarine Work
	Prof A C Seward, F R S	Links with the Past in the Plant World
1912 Dundee	Prof W H Bragg, F R S ..	Radiations Old and New
	Prof A Keith, M D . .	The Antiquity of Man

[1] 'Popular Lectures,' delivered to the citizens of Winnipeg
[2] Repeated, to the public, on Wednesday, September 7

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Lecture
1901 Glasgow	H J Mackinder, M A . .	The Movements of Men by Land and Sea.
1902. Belfast	Prof L C Miall, F R S	Gnats and Mosquitoes
1903 Southport	Dr J S Flett	Martinique and St Vincent the Eruptions of 1902
1904 Cambridge	Dr J. E Marr, F.R S . . .	The Forms of Mountains
1906 York ..	Prof S P Thompson, F R S	The Manufacture of Light.
1907 Leicester	Prof H A Miers, F R S	The Growth of a Crystal
1908 Dublin	Dr A E H Tutton, F R S	The Crystallisation of Water
1910 Sheffield	C T Heycock, F R S	Metallic Alloys
1911 Portsmouth	Dr H R Mill ..	Rain.

PUBLIC LECTURES.

Date and Place	Lecturer	Subject of Lecture
1912 Dundee ...	Prof A Fowler, F R S .	The Sun
	Prof E C K Gonner, M A	Prices and Wages
	Prof B Moore, D Sc	Science and National Health

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1901, Sept 11	Glasgow	Prof A W Rücker, D Sc, Sec.R S	310	37
1902, Sept 10	Belfast	Prof J Dewar, LL D, F R S	243	21
1903, Sept 9	Southport	Sir Norman Lockyer, K C B, F R S	250	21
1904, Aug 17	Cambridge	Rt Hon A J Balfour, M P, F R S	419	32
1905, Aug 15	South Africa	Prof G H. Darwin, LL D, F R S	115	40
1906, Aug 1	York	Prof E. Ray Lankester, LL D, F R S	322	10
1907, July 31	Leicester	Sir David Gill, K C B, F R S	276	19
1908, Sept 2	Dublin	Dr Francis Darwin, F R S	294	24
1909, Aug 25	Winnipeg	Prof Sir J J Thomson, F R S	117	13
1910, Aug 31	Sheffield	Rev. Prof T G Bonney, F R S	293	26
1911, Aug 30	Portsmouth	Prof Sir W Ramsay, K C B, F R S	284	21
1912, Sept 4	Dundee	Prof E A Schäfer, F R S	288	14

¶ Including 848 Members of the South African Association

ANALYSIS OF ATTENDANCES AT

[*The total attendances for the years* 1832,

Average attendance at 76 *Meetings* 1848.

	Average Attendance
Average attendance at 5 Meetings beginning during *June, between* 1833 *and* 1860 . . .	1260
Average attendance at 4 Meetings beginning during *July, between* 1841 *and* 1907	1122
Average attendance at 30 Meetings beginning during *August, between* 1836 *and* 1910 . .	1943 [1]
Average attendance at 35 Meetings beginning during *September, between* 1831 *and* 1908 . .	1944
Attendance at 1 Meeting held in *October, Cambridge*, 1862 .	1161

Meetings beginning during August.

Average attendance at—

4 Meetings beginning during the 1st week in *August*	(1st– 7th) .	1905
5 ,, ,, ,, ,, 2nd ,, ,, ,,	(8th–14th)	2130
8 ,, ,, ,, ,, 3rd ,, ,, ,,	(15th–21st) .	1761 [2]
13 ,, ,, ,, ,, 4th ,, ,, ,,	(22nd–31st) .	1996

[1] Average attendance at 31 Meetings, *including* South Africa, 1905 (August 15–September 1): 1949

at Annual Meetings of the Association—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of Grants for Scientific Purposes	Year
374	131	794	246	20	1912	2046 0 0	945 0 0	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937¶	411	430	181	16	2130	2422 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906
339	61	659	251	42	1647	1561 0 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0 0	1157 18 8	1908
290**	162	789	90	7	1468	1623 0 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0 0	963 17 0	1910
349	61	414	81	31	1241	1176 0 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0 0	845 7 6	1912

** Including 137 Members of the American Association.

THE ANNUAL MEETINGS, 1831–1910.

1835, 1843, *and* 1844 *are unknown.*]

Meetings beginning during September.

Average attendance at—

	Average Attendance
12 Meetings beginning during the 1st week in *September* (1st– 7th)	2100
16 ,, ,, ,, ,, 2nd ,, ,, ,, (8th–14th)	1860
5 ,, ,, ,, ,, 3rd ,, ,, ,, (15th–21st)	2206
2 ,, ,, ,, ,, 4th ,, ,, ,, (22nd–30th)	1025

Meetings beginning during June, July, and October.

Attendance at 1 Meeting (1845, June 19) beginning during the 3rd week in *June* (15th–21st)	1079
Average attendance at 4 Meetings beginning during the 4th week in *June* (22nd–30th)	1306
Attendance at 1 Meeting (1851, July 2) beginning during the 1st week in *July* (1st–7th)	710
Average attendance at 2 Meetings beginning during the 3rd week in *July* (15th–21st)	1066
Attendance at 1 Meeting (1907, July 31) beginning during the 5th week in *July* (29th–31st) . .	1647
Attendance at 1 Meeting (1862, October 1) beginning during the 1st week in *October* (1st–7th) . .	1161

[2] Average attendance at 9 Meetings, *including* South Africa, 1905 (August 15–September 1). 1802.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes, 1901-1911.

1901

	£	s.	d
Electrical Standards	45	0	0
Seismological Observations..	75	0	0
Wave-length Tables	4	14	0
Isomorphous Sulphonic Derivatives of Benzene .	35	0	0
Life-zones in British Carboniferous Rocks	20	0	0
Underground Water of North-west Yorkshire .	50	0	0
Exploration of Irish Caves	15	0	0
Table at the Zoological Station, Naples . ..	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	75	0	0
Migration of Birds	10	0	0
Terrestrial Surface Waves	5	0	0
Changes of Land-level in the Phlegræan Fields	50	0	0
Legislation regulating Women's Labour	15	0	0
Small Screw Gauge .	45	0	0
Resistance of Road Vehicles to Traction	75	0	0
Silchester Excavation .	10	0	0
Ethnological Survey of Canada	30	0	0
Anthropological Teaching	5	0	0
Exploration in Crete . .	145	0	0
Physiological Effects of Peptone	30	0	0
Chemistry of Bone Marrow	5	15	11
Suprarenal Capsules in the Rabbit ..	5	0	0
Fertilisation in Phæophyceæ	15	0	0
Morphology, Ecology, and Taxonomy of Podostemaceæ	20	0	0
Corresponding Societies Committee	15	0	0
	£920	9	11

1902.

	£	s.	d.
Electrical Standards.. ..	40	0	0
Seismological Observations	35	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	80	0	0
Relation between Absorption Spectra and Organic Substances	20	0	0
Wave-length Tables . ..	5	0	0
Life-zones in British Carboniferous Rocks . .	10	0	0
Exploration of Irish Caves	45	0	0
Table at the Zoological Station, Naples . . .	100	0	0
Index Generum et Specierum Animalium . . .	100	0	0
Migration of Birds	15	0	0
Structure of Coral Reefs of Indian Ocean .	50	0	0
Compound Ascidians of the Clyde Area .	25	0	0
Terrestrial Surface Waves	15	0	0
Legislation regulating Women's Labour . .	30	0	0
Small Screw Gauge .	20	0	0
Resistance of Road Vehicles to Traction .	50	0	0
Ethnological Survey of Canada	15	0	0
Age of Stone Circles	30	0	0
Exploration in Crete	100	0	0
Anthropometric Investigation of Native Egyptian Soldiers	15	0	0
Excavations on the Roman Site at Gelligaer	5	0	0
Changes in Hæmoglobin	15	0	0
Work of Mammalian Heart under Influence of Drugs	20	0	0
Investigation of the Cyanophyceæ .. .	10	0	0
Reciprocal Influence of Universities and Schools	5	0	0
Conditions of Health essential to carrying on Work in Schools	2	0	0
Corresponding Societies Committee	15	0	0
	£947	0	0

1903

	£	s.	d.
Electrical Standards	35	0	0
Seismological Observations.	40	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	40	0	0
Study of Hydro-aromatic Substances	20	0	0
Erratic Blocks	10	0	0
Exploration of Irish Caves ..	40	0	0
Underground Waters of North-west Yorkshire	40	0	0

	£	s.	d.
Life-zones in British Carboniferous Rocks	5	0	0
Geological Photographs	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Tidal Bore, Sea Waves, and Beaches	15	0	0
Scottish National Antarctic Expedition	50	0	0
Legislation affecting Women's Labour	25	0	0
Researches in Crete	100	0	0
Age of Stone Circles	3	13	2
Anthropometric Investigation	5	0	0
Anthropometry of the Todas and other Tribes of Southern India	50	0	0
The State of Solution of Proteids	20	0	0
Investigation of the Cyanophyceæ	25	0	0
Respiration of Plants	12	0	0
Conditions of Health essential for School Instruction	5	0	0
Corresponding Societies Committee	20	0	0
	£845	13	2

1904

	£	s.	d.
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	50	0	0
Magnetic Observations at Falmouth	60	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	25	0	0
Erratic Blocks	10	0	0
Life-zones in British Carboniferous Rocks	35	0	0
Fauna and Flora of the Trias	10	0	0
Investigation of Fossiliferous Drifts	50	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	60	0	0
Development in the Frog	15	0	0
Researches on the Higher Crustacea	15	0	0
British and Foreign Statistics of International Trade	25	0	0
Resistance of Road Vehicles to Traction	90	0	0
Researches in Crete	100	0	0
Researches in Glastonbury Lake Village	25	0	0
Anthropometric Investigation of Egyptian Troops	8	10	0
Excavations on Roman Sites in Britain	25	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	40	0	0
Botanical Photographs	4	8	11
Respiration of Plants	15	0	0
Experimental Studies in Heredity	35	0	0
Corresponding Societies Committee	20	0	0
	£887	8	11

1905

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	40	0	0
Magnetic Observations at Falmouth	50	0	0
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism	20	0	0
Aromatic Nitramines	25	0	0
Fauna and Flora of the British Trias	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	75	0	0
Development of the Frog	10	0	0
Investigations in the Indian Ocean	150	0	0
Trade Statistics	4	4	8
Researches in Crete	75	0	0
Anthropometric Investigations of Egyptian Troops	10	0	0
Excavations on Roman Sites in Britain	10	0	0
Anthropometric Investigations	10	0	0
Age of Stone Circles	30	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	30	0	0
Ductless Glands	40	0	0
Botanical Photographs	3	17	6
Physiology of Heredity	35	0	0
Structure of Fossil Plants	50	0	0
Corresponding Societies Committee	20	0	0
	£928	2	2

1906.

	£	s	d
Electrical Standards	25	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	50	0	0
Magnetic Survey of South Africa	99	12	6
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Aromatic Nitramines	10	0	0
Fauna and Flora of the British Trias	7	8	11
Crystalline Rocks of Anglesey	30	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Frog	10	0	0
Higher Crustacea	15	0	0
Freshwater Fishes of South Africa	50	0	0
Rainfall and Lake and River Discharge	10	0	0
Excavations in Crete	100	0	0
Lake Village at Glastonbury	40	0	0
Excavations on Roman Sites in Britain	30	0	0
Anthropometric Investigations in the British Isles	30	0	0
State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	20	0	0
Effect of Climate upon Health and Disease	20	0	0
Research on South African Cycads	14	19	4
Peat Moss Deposits	25	0	0
Studies suitable for Elementary Schools	5	0	0
Corresponding Societies Committee	25	0	0
	£882	0	9

1907

	£	s	d
Electrical Standards	50	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	40	0	0
Magnetic Survey of South Africa	25	7	6
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	30	0	0
Life Zones in British Carboniferous Rocks	10	0	0
Erratic Blocks	10	0	0
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone of South-West England	15	0	0
Correlation and Age of South African Strata, &c	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Sexual Cells	1	11	8
Oscillations of the Land Level in the Mediterranean Basin	50	0	0
Gold Coinage in Circulation in the United Kingdom	8	19	7
Anthropometric Investigations in the British Isles	10	0	0
Metabolism of Individual Tissues	45	0	0
The Ductless Glands	25	0	0
Effect of Climate upon Health and Disease	55	0	0
Physiology of Heredity	30	0	0
Research on South African Cycads	35	0	0
Botanical Photographs	5	0	0
Structure of Fossil Plants	5	0	0
Marsh Vegetation	15	0	0
Corresponding Societies Committee	16	14	1
	£757	12	10

1908.

	£	s	d
Seismological Observations	40	0	0
Further Tabulation of Bessel Functions	15	0	0
Investigation of Upper Atmosphere by means of Kites	25	0	0
Meteorological Observations on Ben Nevis	25	0	0
Geodetic Arc in Africa	200	0	0
Wave length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	40	0	0
Transformation of Aromatic Nitramines	30	0	0
Erratic Blocks	17	16	6
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
Pre-Devonian Rocks	10	0	0
Exact Significance of Local Terms	5	0	0
Composition of Charnwood Rocks	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Hereditary Experiments	10	0	0

	£	s	d
Fauna of Lakes of Central Tasmania	40	0	0
Investigations in the Indian Ocean	50	0	0
Exploration in Spitsbergen	30	0	0
Gold Coinage in Circulation in the United Kingdom	3	7	6
Electrical Standards	50	0	0
Glastonbury Lake Village	30	0	0
Excavations on Roman Sites in Britain	15	0	0
Age of Stone Circles	50	0	0
Anthropological Notes and Queries	40	0	0
Metabolism of Individual Tissues	40	0	0
The Ductless Glands	13	14	8
Effect of Climate upon Health and Disease	35	0	0
Body Metabolism in Cancer	30	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Marsh Vegetation	15	0	0
Succession of Plant Remains	18	0	0
Corresponding Societies Committee	25	0	0
	£1157	18	8

1909

	£	s	d
Seismological Observations	60	0	0
Investigation of the Upper Atmosphere by means of Kites	10	0	0
Magnetic Observations at Falmouth	50	0	0
Establishing a Solar Observatory in Australia	50	0	0
Wave-length Tables of Spectra	9	16	0
Study of Hydro aromatic Substances	15	0	0
Dynamic Isomerism	35	0	0
Transformation of Aromatic Nitramines	10	0	0
Electroanalysis	30	0	0
Fauna and Flora of British Trias	8	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	8	0	0
Palæozoic Rocks of Wales and the West of England	9	0	0
Igneous and Associated Sedimentary Rocks of Glensaul	11	13	9
Investigations at Biskra	50	0	0
Table at the Zoological Station at Naples	100	0	0
Heredity Experiments	10	0	0
Feeding Habits of British Birds	5	0	0
Index Animalium	75	0	0
Investigations in the Indian Ocean	35	0	0
Gaseous Explosions	75	0	0
Excavations on Roman Sites in Britain	5	0	0
Age of Stone Circles	30	0	0
Researches in Crete	70	0	0
The Ductless Glands	35	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Reflex Muscular Rhythm	10	0	0
Anæsthetics	25	0	0
Mental and Muscular Fatigue	27	0	0
Structure of Fossil Plants	5	0	0
Botanical Photographs	10	0	0
Experimental Study of Heredity	30	0	0
Symbiosis between Turbellarian Worms and Algæ	10	0	0
Survey of Clare Island	65	0	0
Curricula of Secondary Schools	5	0	0
Corresponding Societies Committee	21	0	0
	£1014	9	9

1910

	£	s	d
Measurement of Geodetic Arc in South Africa	100	0	0
Republication of 'Electrical Standards Reports	100	0	0
Seismological Observations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism	35	0	0
Transformation of Aromatic Nitro-amines	15	0	0
Electroanalysis	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
South African Strata	5	0	0
Fossils of Midland Coalfields	25	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Heredity Experiments	15	0	0
Feeding Habits of British Birds	5	0	0
Amount and Distribution of Income	15	0	0
Gaseous Explosions	75	0	0
Lake Villages in the neighbourhood of Glastonbury	5	0	0
Excavations on Roman Sites in Britain	5	0	0
Neolithic Sites in Northern Greece	5	0	0

	£	s	d
The Ductless Glands	40	0	0
Body Metabolism in Cancer	20	0	0
Anæsthetics	25	0	0
Tissue Metabolism	25	0	0
Mental and Muscular Fatigue	18	17	0
Electromotive Phenomena in Plants.	10	0	0
Structure of Fossil Plants .	10	0	0
Experimental Study of Heredity... . .	30	0	0
Survey of Clare Island .. .	30	0	0
Corresponding Societies Committee. .	20	0	0
	£963	17	0

1911

	£	s	d
Seismological Investigations	60	0	0
Magnetic Observations at Falmouth .	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Grant to International Commission on Physical and Chemical Constants .	30	0	0
Study of Hydro-aromatic Substances ..	20	0	0
Dynamic Isomerism	25	0	0
Transformation of Aromatic Nitro amines	15	0	0
Electroanalysis .	15	0	0
Influence of Carbon, &c, on Corrosion of Steel . . .	15	0	0
Crystalline Rocks of Anglesey	2	0	0
Mammalian Fauna in Miocene Deposits, Bugti Hills, Baluchistan	75	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Feeding Habits of British Birds	5	0	0
Belmullet Whaling Station...	30	0	0
Map of Prince Charles Foreland...	30	0	0
Gaseous Explosions	90	0	0
Lake Villages in the neighbourhood of Glastonbury.	5	0	0
Age of Stone Circles	30	0	0
Artificial Islands in Highland Lochs	10	0	0
The Ductless Glands	40	0	0
Anæsthetics	20	0	0
Mental and Muscular Fatigue	25	0	0
Electromotive Phenomena in Plants...	10	0	0
Dissociation of Oxy-Hæmoglobin	25	0	0
Structure of Fossil Plants	15	0	0
Experimental Study of Heredity	45	0	0
Survey of Clare Island. . .	20	0	0
Registration of Botanical Photographs	10	0	0
Mental and Physical Factors involved in Education	10	0	0
Corresponding Societies Committee . . .	20	0	0
	£922	0	0

REPORT OF THE COUNCIL, 1911-1912.

I Sir William H White, K C B , F R S , has been unanimously nominated by the Council to fill the office of President of the Association for 1913 (Birmingham Meeting).

II The Association was represented at the funeral of Lord Lister by Sir William Ramsay (President), Professor J. Perry (General Treasurer), and Major P. A. MacMahon (General Secretary)

A letter was received from the Board of Education expressing regret at the death of Lord Lister, and enclosing copy of a letter from the German Ambassador, conveying condolences 'to the official departments interested, and in particular to the institutions of which the deceased man of science was President '

By invitation of the Presidents of the Royal Society and the Royal College of Surgeons, the Council has nominated Prof E A Schafer, President-elect, to serve upon a Committee to consider and take steps for the creation of a Memorial to Lord Lister

Sir William Ramsay has been appointed to represent the Association at the International Congress of Applied Chemistry in Washington, September 4, 1912.

III The following Address has been presented

To the President and Council of the Royal Society

We, the President and Council of the British Association for the Advancement of Science, offer our cordial congratulations to the Royal Society on the occasion of the celebration of the two hundred and fiftieth anniversary of the foundation of the Society

The British Association, since its birth in 1831, has been constantly in close relations with the Society The great majority, not only of those who took the leading parts in the foundation of the Association, but of those who have filled its presidential chair, besides many others to whose earnest co-operation the success of its annual meetings has been due, have been Fellows of the Society.

We would express the hope that the Society may continue to prosper, and may always maintain that pre-eminent position which is the fitting reward of its labours

Signed, on behalf of the Council,

William Ramsay,
President.

IV The Council has received from the Secretary of State for the Colonies a full reply to the representations made by the Association in regard to the preservation of antiquities in Cyprus The Council has expressed to him the thanks of the Association for the interest which he has shown in this matter, and its hope that the measures of preservation announced in his communication may have the desired effect

V. A RESOLUTION has been received

From the Committee of Recommendations

'That the Council be requested to consider the present practice of reckoning unspent balances of grants as part of the funds available for redistribution, and to report if any alteration in the practice is advisable.'

It was reported to the Council that certain Research Committees had found it a hardship to be expected to return unspent balances of grants early in the summer following their first appointment.

The Council therefore resolved to propose:—

(*a*) To set aside the Standing Order passed at the Dublin Meeting in 1908, under which any balance of a grant remaining unexpended at the time of the Annual Meeting next after that at which the grant was made, must be regarded as having reverted to the funds of the Association.

(*b*) To amend Rule 6, chap iv., as follows, viz.:—

To omit these words:—

The Chairman must then either return the balance of the grant, if any, which remains unexpended, or, if further expenditure be contemplated, apply for leave to retain the balance.

and *to substitute*:—

The Chairman must then return the balance of the grant, if any, which remains unexpended; provided that a Research Committee may, in the first year of its appointment only, apply for leave to retain an unexpended balance when or before its report is presented, due reason being given for such application.

VI. A Resolution, referred to the Council by the General Committee at Portsmouth, has been received

From Sections D and H

'That the Council be approached with the view of requesting His Majesty's Government to equip a vessel for the purpose of making a biological and anthropological exploration in Oceania at the close of the meeting of the British Association in Australia in 1914.'

The Council appointed the following Committee to report on any necessary steps in this connection: The President and General Officers, Professor G. C. Bourne, and Dr. A C. Haddon. On the report of this Committee, it was resolved that no immediate action be taken, but that the Committee be allowed to remain in being, with a view to advising the Council as occasion might arise in the future.

VII. A Resolution, referred to the Council by the General Committee at Portsmouth, has been received

From Section H.

'That this Association co-operate with the Royal Anthropological Institute in urging upon His Majesty's Government the desirability of instituting an Imperial Bureau of Anthropology, and that the General Officers be empowered to take such action as may be necessary for this purpose.'

It was reported to the Council that a letter had been received from the Royal Anthropological Institute, intimating the intention of the Council of the Institute to issue a memorial on the above subject to Cabinet Ministers, and to include therein the substance of the above recommendation. The Council of the Association were invited to appoint a representative on a deputation to wait on the Colonial Secretary, and perhaps also on the Prime Minister. Sir William Ramsay (President) was accordingly appointed to serve on such deputation if arranged.

VIII A Resolution, referred to the Council by the General Committee at Portsmouth, has been received

From Section I.

'With reference to Dr. A. D. Waller's paper on the Claim of Sir Charles Bell to the Discovery of Motor and Sensory Nerve Channels:

'(1) The author of this paper has called the attention of the Sectional Committee to the fact that his communication conveys a serious charge relating to the republication by Bell, in 1824 and subsequently, of papers originally published in the "Phil. Trans." of the Royal Society in 1821.

'(2) In view of the importance attaching to the real authorship of the discovery of the distinction between motor and sensory nerves we have examined the printed documents quoted at pp. 12, 13, and verified the accuracy of the quotations given by Dr. Waller of the original passages of 1821 and of the republished passages of 1824.

'(3) In our opinion it will be necessary to reconsider carefully the claim first put forward by Bell in 1824 to the discovery of the distinction between motor and sensory nerves

'(4) Dr. Waller's paper on the subject contains sufficient grounds for the revision of the conclusion published in the Report of the British Association for 1833, and we recommend that it be published *in extenso* in the Report of the present year.

'(5) In view of the importance of the historical claim of Bell, we recommend that a Committee be appointed to consider the case fully, and report upon it.

'(6) In spite of the fact that many years have elapsed since November 12, 1824, we are of opinion that a formal communication should be made to the Royal Society, calling its attention to the existence of a spurious version of papers received by the Royal Society and published on its authority on July 12, 1821.

'(7) The Sectional Committee recommends that the text of the foregoing resolutions be printed as an Appendix to Dr Waller's paper.'

The Council resolved to take no further action.

IX In accordance with Recommendations received by the General Committee at Portsmouth and referred to the Council, it was agreed that the following Committees be authorised to receive contributions from sources other than the Association:—

'To aid Investigators . . to carry on . . . work at the Zoological Station at Naples' (*Section D*)

'To conduct Explorations with a view to ascertaining the Age of Stone Circles.' (*Section H*)

'To investigate the Physical Characters of the Ancient Egyptians.' (*Section H*)

X The Council, having been made aware of an opinion, held in various quarters, that more lectures than the one hitherto given to the operative classes should be provided for the public at places of meeting, have on the present occasion arranged three public lectures, open to those who have not joined the Association, at the request of the Local Executive Committee in Dundee

XI The Council have had under consideration:—

(a) An instruction to the General Officers from the General Committee at Portsmouth, to inquire into the possibility of improving the means of obtaining abstracts of papers previously to their reading;

(b) A motion to inquire as to whether the publication of the Annual Volume confers a benefit to science in any way commensurate with its cost,

(c) The report of a Committee appointed by the Council This report brought to the notice of the Council, *inter alia*, the increase which has recently taken place in ruling prices for printing.

The Council, after full inquiry, have, with the above considerations in view, given certain instructions to the Officers as to the contents and arrangement of the Volume, and as to the issue of printed matter at Annual Meetings

XII. The following NOMINATIONS are made by the Council —

Conference of Delegates.—Professor F O. Bower (*Chairman*), Mr H W. T. Wager (*Vice-Chairman*), Mr. W P. D. Stebbing (*Secretary*).

Corresponding Societies Committee.—Mr W Whitaker (*Chairman*), Mr W. P. D Stebbing (*Secretary*), Rev J O Bevan, Sir Edward Brabrook, Dr J G Garson, Principal E H Griffiths, Dr. A. C. Haddon, Mr T. V. Holmes, Mr J Hopkinson, Mr. A. L. Lewis, Mr F W. Rudler, Rev T. R R Stebbing, and the President and General Officers of the Association.

XIII The Council have received reports from the General Treasurer during the past year His ACCOUNTS from July 1, 1911, to June 30, 1912, have been audited and are presented to the General Committee

XIV. In accordance with the Regulations the retiring members of he Council are:—

Professor E B Poulton and Sir W. Abney (retiring by seniority), Dr A. E H Tutton (by least attendance), Sir W H. White (to become a Member ex-officio as President-elect in 1912-13), Col. C. F. Close (resigned)

The Council have nominated the following new members.—

Dr Dugald Clark,
Prof A Dendy,
Capt H G Lyons,

leaving two vacancies to be filled by the General Committee without nomination by the Council

The full list of nominations of ordinary members is as follows —

Dr Tempest Anderson
Prof H E Armstrong
Sir E Brabrook
Sir Lauder Brunton
Dr Dugald Clark
Major P G. Craigie.
W Crooke
Prof A Dendy
Principal E H Griffiths
Dr A C Haddon.
A D Hall
Prof W D. Halliburton
E Sidney Hartland
Capt H G Lyons
Dr J E Marr
Prof. R Meldola
Dr. P. Chalmers Mitchell
Prof J L Myres
Col D Prain
Prof C S Sherrington
J J H Teall
Prof S P Thompson
Prof F T Trouton

XV The GENERAL OFFICERS have been nominated by the Council for reappointment.

XVI The following have been admitted as members of the General Committee —

Dr E A Newell Arber, Prof B H Bentley, Rev A L Cortie, S J , G F Daniell, Dr W H Eccles, G W Grabham, B Hobson, Dr C A Matley, J H Milton, T Sheppard, Dr W F G Swann, Dr T F Wall, A C Young

Dr. THE GENERAL TREASURER IN ACCOUNT ADVANCEMENT OF SCIENCE,

1911-1912. RECEIPTS

	£	s.	d.
Balance brought forward	353	13	5
Life Compositions (including Transfers)	314	0	0
New Annual Members' Subscriptions	178	0	0
Annual Subscriptions	628	0	0
Sale of Associates' Tickets	406	0	0
Sale of Ladies' Tickets	80	0	0
Sale of Publications	266	9	11
Dividends on Consols	150	14	3
Dividends on India 3 per Cent Stock	101	14	0
Great Indian Peninsula Railway 'B' Annuity	49	5	6
Interest at Portsmouth Bank	2	0	8
Sale of Consols	626	3	0

Unexpended Balances of Grants returned	£	s	d			
Botanical Photographs	4	12	7			
Electroanalysis	0	11	7			
Corrosion of Steel	4	1	1			
				9	5	3

Mem · Receipts on account of the Dundee Meeting (1912) amounting to £49 5*s*, and a sum of £100 returnable, are not included in this Account, but are paid in to a Separate (No 2) Account at the Bank.

Investments

Nominal Amount. £	s	d		Value at 29th June, 1912 £	s.	d.
5,701	10	3	2½ per Cent Consolidated Stock	4,354	10	9
3,600	0	0	India 3 per Cent. Stock	2,808	0	0
1,493	6	6	£73 Great Indian Peninsula Railway 'B' Annuity (cost)	1,533	0	0
				8,695	10	9
73	12	3	Sir Frederick Bramwell's Gift — 2½ per Cent Self-cumulating Consolidated Stock	56	4	3
			[To be awarded in 1931 for a paper 'dealing with the whole question of the prime movers of 1931, and especially with the then relation between steam engines and internal combustion engines']			
				£8,751	15	0

£3,165 6 0

JOHN PERRY, *General Treasurer*

WITH THE BRITISH ASSOCIATION FOR THE *Cr.*

July 1, 1911, to June 30, 1912.

1911-1912 PAYMENTS.

	£ s d	£ s d
Rent and Office Expenses		102 10 5
Salaries, &c.		706 19 9
Printing, Binding, &c		1,158 14 9
Expenses of Portsmouth Meeting		121 17 10
Grants made at Portsmouth —	£ s d	
Seismological Investigations	60 0 0	
Magnetic Observations at Falmouth	25 0 0	
Investigation of the Upper Atmosphere	30 0 0	
Grant to International Commission on Physical and Chemical Constants	30 0 0	
Further Tabulation of Bessel Functions	15 0 0	
Study of Hydro-aromatic Substances	20 0 0	
Dynamic Isomerism	30 0 0	
Transformation of Aromatic Nitroamines	10 0 0	
Electroanalysis	10 0 0	
Study of Plant Enzymes	30 0 0	
Erratic Blocks	5 0 0	
Igneous and Associated Rocks of Glensaul, &c.	15 0 0	
List of Characteristic Fossils	5 0 0	
Sutton Bone Bed	15 0 0	
Bembridge Limestone at Creechbarrow Hill	20 0 0	
Table at the Zoological Station at Naples	50 0 0	
Index Animalium	75 0 0	
Belmullet Whaling Station	20 0 0	
Secondary Sexual Characters in Birds	10 0 0	
Gaseous Explosions	60 0 0	
Lake Villages in the neighbourhood of Glastonbury	5 0 0	
Artificial Islands in Highland Lochs	10 0 0	
Physical Character of Ancient Egyptians	40 0 0	
Excavations in Easter Island	15 0 0	
The Ductless Glands	35 0 0	
Calorimetric Observations on Man	40 0 0	
Structure of Fossil Plants	15 0 0	
Experimental Study of Heredity	35 0 0	
Survey of Clare Island	20 0 0	
Jurassic Flora of Yorkshire	15 0 0	
Overlapping between Secondary and Higher Education	1 18 6	
Curricula, &c., of Industrial and Poor Law Schools	10 0 0	
Influence of School Books upon Eyesight	3 9 0	
Corresponding Societies Committee	25 0 0	
Collections illustrating Natural History of Isle of Wight	40 0 0	
		845 7 6
		£2,935 10 3
Balance at Bank of England (Western Branch)	290 11 2	
Cash not paid in	6 0 0	
	£296 11 2	
Less Cheques not presented	66 15 5	
		229 15 9
		£3,165 6 0

An account of about £760 is outstanding due to Messrs. Spottiswoode & Co.

I have examined the above Account with the Books and Vouchers of the Association, and certify the same to be correct. I have also verified the Balance at the Bankers, and have ascertained that the Investments are registered in the names of the Trustees.

Approved—
HERBERT McLEOD, } *Auditors.*
EDWARD BRABROOK, }
July 26, 1912.

W. B. KEEN, *Chartered Accountant.*

GENERAL MEETINGS AT DUNDEE

On Wednesday, September 4, at 8.30 P.M., in the Kinnaird Hall, a communication was read from Sir William Ramsay, K.C.B., F.R.S., who was unavoidably absent, resigning the office of President to Professor E. A. Schafer, F.R.S., who took the Chair and delivered an Address, for which see p. 3.

On Thursday, September 5, at 8.30 P.M., the Lord Provost and Mrs. Urquhart held a Reception and Conversazione in the Drill Hall.

On Friday, September 6, at 8.30 P.M., in the Kinnaird Hall, Professor W. H. Bragg, F.R.S., delivered a Discourse on 'Radiations Old and New.'

On Monday, September 9, at 8.30 P.M., in the Kinnaird Hall, Professor A. Keith, M.D., delivered a Discourse on 'The Antiquity of Man.'

On Tuesday, September 10, at 9 P.M., a Ball was given in the Drill Hall, by invitation of the Local Executive Committee.

On Wednesday, September 11, at 3 P.M., the concluding General Meeting was held in the Foresters' Hall, when the following Resolutions were adopted:—

1. That the cordial thanks of the Association be given to the Honourable the Lord Provost, the Magistrates, and the Town Council of Dundee for the hearty welcome accorded to this Meeting; and to the citizens for their unbounded hospitality.

2. That a cordial vote of thanks be given to the Council and Professors of University College, to the governing bodies of the Chamber of Commerce, the Technical College, and other Institutions, for their kindness in placing their buildings and resources at the disposal of the Association.

3. That a cordial vote of thanks be given to the Provosts and Magistrates of the Royal Burghs of St. Andrews, Dunfermline, and Arbroath, and to the other public bodies, directors of works, and private hosts, who have contributed by means of excursions and garden parties, and in other ways, to the entertainment of the members.

4. That a cordial vote of thanks be given to the Ladies' Reception Committee for the admirable arrangements made for the Meeting.

5. That a cordial vote of thanks be given to the Local Officers and Executive Committees for the admirable arrangements made for the Meeting.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE DUNDEE MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Prof. H. L. Callendar, LL.D., F.R.S. *Vice-Presidents.*—Prof. H. M. MacDonald, F.R.S.; Prof. W. Peddie, Ph.D., Prof. R. A. Sampson, F.R.S., Prof. F. T. Trouton, F.R.S.; Prof. H. H. Turner, F.R.S. *Secretaries.*—Prof. A. W. Porter, F.R.S. (*Recorder*); Prof. P. V. Bevan, Sc.D.; E. Gold, M.A.; H. B. Heywood, D.Sc., F. J. M. Stratton, M.A.; R. Norrie, M.A.; W. G. Robson, A.R.C.S.

SECTION B.—CHEMISTRY.

President.—Prof. A. Senier, M.D., Ph.D. *Vice-Presidents.*—T. Fairley, F.R.S.E.; Prof. A. F. Holleman, Ph.D.; Prof. J. C. Irvine, D.Sc.; Prof. A. Liversidge, F.R.S.; Prof. H. Marshall, F.R.S. *Secretaries.*—Dr. E. F. Armstrong (*Recorder*); Dr. C. H. Desch; Dr. A. Holt; Dr. J. K. Wood.

SECTION C.—GEOLOGY.

President.—Dr. B. N. Peach, F.R.S. *Vice-Presidents.*—Prof. C. Barrois, D. ès Sc.; W. Lower Carter, M.A.; Sir Archibald Geikie, K.C.B., F.R.S.; Dr. John Horne, F.R.S.; Prof. T. J. Jehu, M.D. *Secretaries.*—Dr. A. R. Dwerryhouse, D.Sc. (*Recorder*); Prof. W. S. Boulton; A. W. R. Don; Prof. S. H. Reynolds, M.A.

SECTION D.—ZOOLOGY.

President.—P. Chalmers Mitchell, D.Sc., F.R.S. *Vice-Presidents.*—Prof. A. Denby, F.R.S.; Prof. Ch. Julin; Prof. F. Keibel; Prof. E. A. Minchin, F.R.S.; Prof. R. Rhumbler; Prof. D'Arcy W. Thompson, C.B. *Secretaries.*—Dr. H. W. Marett Tims (*Recorder*); Dr. J. H. Ashworth; R. Douglas Laurie, M.A.; Miss D. L. M'Kinnon, B.Sc.

SECTION E.—GEOGRAPHY.

President.—Colonel Sir Charles M. Watson, K.C.M.G., C.B., R.E. *Vice-Presidents.*—R. B. Don, M.A.; Colonel H. W. Feilden, C.B.; Dr. Tempest Anderson; Dr. J. Scott Keltie; Colonel Sir D. A. Johnston, K.C.M.G.; Sir Clements Markham, K.C.B., F.R.S. *Secretaries.*—Rev. W. J. Barton, M.A. (*Recorder*); J. McFarlane, M.A.; E. A. Reeves; D. Wylie.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—Sir Henry H. Cunynghame, K.C.B. *Vice-Presidents.*—Prof. S. J. Chapman, M.Com.; Prof. P. Geddes; W. MacKenzie; Sir Edward Brabrook, C.B.; Ven. Archdeacon Cunningham, D.D.; James Cunningham, M.A. *Secretaries.*—Dr. W. R. Scott, M.A. (*Recorder*); C. R. Fay, M.A.; Elmslie Tosh.

SECTION G.—ENGINEERING.

President.—Prof. A. Barr, D.Sc. *Vice-Presidents.*—Prof. J. H. Biles, LL.D.; Prof. A. H. Gibson, D.Sc.; Prof. Kennelly; William Low; W. B. Thompson; Sir John Wolfe-Barry, K.C.B., F.R.S. *Secretaries.*—Prof. E. G. Coker, D.Sc. (*Recorder*); A. R. Fulton, B.Sc.; H. Richardson; A. A. Rowse, B.Sc.; H. E. Wimperis, M.A.

SECTION H.—ANTHROPOLOGY.

President.—Prof. G. Elliot Smith, M.D., F.R.S. *Vice-Presidents.*—Prof. R. Anthony; Prof. R. C. Bosanquet, M.A.; Prof. T. H. Bryce, M.D.; W. H. R. Rivers, F.R.S. *Secretaries.*—E. N. Fallaize, B.A. (*Recorder*); D. D. Craig, M.A.; E. W. Martindell, M.A.; F. C. Shrubsall, M.A., M.D.

SECTION I.—PHYSIOLOGY.

President.—Leonard Hill, M.B., F.R.S. *Vice-Presidents.*—Prof. Paul Heger; Prof. Hugo Kronecker; Prof. J. S. Macdonald, B.A.; C. S. Myers, M.D.; Prof. Waymouth Reid, F.R.S.; Prof. Max Verworn. *Secretaries.*—Dr. H. E. Roaf (*Recorder*); Dr. Keith Lucas; W. Moodie, M.B.; Dr. J. Tait.

SECTION K.—BOTANY.

President.—Prof. F. A. Keeble, Sc.D. *Vice-Presidents*.—Prof. F. O. Bower, F.R.S.; Dr. R. A. Robertson, Harold Wager, F.R.S., Prof. F. E. Weiss, D.Sc. *Secretaries*.—Prof. D. T. Gwynne-Vaughan, M.A. (*Recorder*), J. Brebner, M.A., C. E. Moss, D.Sc., D. Thoday, M.A.

SECTION L.—EDUCATIONAL SCIENCE.

President.—Prof. J. Adams, M.A. *Vice-Presidents*.—W. D. Eggar, M.A., Sir George Fordham, J. L. Holland, B.A., J. Malloch, M.A., Dr. M. Sadler. *Secretaries*.—Prof. J. A. Green, M.A. (*Recorder*), D. Berridge, M.A., Dr. J. Davidson, M.A., H. Richardson, M.A.

SECTION M.—AGRICULTURE.

President.—T. H. Middleton, M.A. *Vice-Presidents*.—W. Bateson, M.A., F.R.S., Major P. G. Craigie, C.B., W. S. Ferguson, A. D. Hall, M.A., F.R.S., Colonel R. G. Wardlaw Ramsay, Dr. D. Wilson, M.A. *Secretaries*.—Dr. E. J. Russell (*Recorder*), C. Crowther, M.A., J. Golding, Dr. A. Lauder.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES.

Chairman.—Prof. F. O. Bower, F.R.S. *Vice-Chairman*.—Harold Wager, F.R.S. *Secretary*.—W. P. D. Stebbing.

COMMITTEE OF RECOMMENDATIONS.

The President and Vice-Presidents of the Association, the General Secretaries, the General Treasurer, the Trustees; the Presidents of the Association in former years, the Chairman of the Conference of Delegates, Prof. H. L. Callendar; Principal Griffiths; Prof. A. Senier, Dr. E. F. Armstrong, Dr. B. N. Peach, Dr. Dwerryhouse, Dr. P. Chalmers Mitchell, Dr. Marett Tims, Sir Charles Watson, Rev. W. J. Barton, Sir H. H. Cunynghame, Dr. W. R. Scott, Prof. A. Barr, Dr. Dugald Clerk, Prof. Elliot Smith, E. N. Fallaize, Leonard Hill, Dr. H. E. Roaf, Prof. F. Keeble; Prof. D. T. Gwynne-Vaughan, Prof. J. Adams, Prof. J. A. Green, T. H. Middleton, Dr. E. J. Russell.

LIST OF GRANTS—DUNDEE, 1912.

RESEARCH COMMITTEES, ETC., APPOINTED BY THE GENERAL COMMITTEE AT THE DUNDEE MEETING: SEPTEMBER 1912.

1. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee	Grants
	SECTION A.—MATHEMATICS AND PHYSICS.	
		£ s d
Seismological Observations	*Chairman*.—Professor H. H. Turner. *Secretary*.—Dr. J. Milne. Mr. C. V. Boys, Sir George Darwin, Mr. Horace Darwin, Dr. R. T. Glazebrook, Mr. M. H. Gray, Mr. R. K. Gray, Professors J. W. Judd, C. G. Knott, and R. Meldola, Mr. R. D. Oldham, Professor J. Perry, Mr. W. E. Plummer, Dr. R. A. Sampson, and Professor A. Schuster	60 0 0*
Investigation of the Upper Atmosphere	*Chairman*.—Dr. W. N. Shaw. *Secretary*.—Mr. E. Gold. Mr. D. Archibald, Mr. C. Vernon Boys, Mr. C. J. P. Cave, Mr. W. H. Dines, Dr. R. T. Glazebrook, Professor J. E. Petavel, Dr. A. Schuster, Dr. W. Watson, and Sir J. Larmor	50 0 0
Grant to the International Commission on Physical and Chemical Constants	*Chairman*.—Sir W. Ramsay. *Secretary*.—Dr. N. T. M. Wilsmore	40 0 0
The further Tabulation of Bessel and other Functions	*Chairman*.—Professor M. J. M. Hill. *Secretary*.—Dr. J. W. Nicholson, Mr. J. R. Airey, Professor Alfred Lodge, Professor L. N. G. Filon, Sir G. Greenhill, and Professor A. G. Webster	30 0 0
	SECTION B.—CHEMISTRY.	
The Study of Hydro-aromatic Substances.	*Chairman*.—Professor W. H. Perkin. *Secretary*.—Professor A. W. Crossley. Dr. M. O. Forster, Dr. Le Sueur, and Dr. A. McKenzie.	20 0 0

* In addition, the Council was authorised to expend a sum not exceeding £70 for the printing of circulars, etc., in connection with the Committee on Seismological Observations.

1 *Receiving Grants of Money*—continued

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s d.
Dynamic Isomerism	*Chairman* —Professor H. E Armstrong *Secretary* —Dr T M Lowry Professor Sydney Young, Dr Desch, Dr J J Dobbie, and Dr M O. Forster	30 0 0
The Transformation of Aromatic Nitroamines and allied substances, and its relation to Substitution in Benzene Derivatives	*Chairman* —Professor F S Kipping *Secretary* —Professor K J P Orton Dr S Ruhemann, and Dr J T Hewitt	20 0 0
The Study of Plant Enzymes, particularly with relation to Oxidation	*Chairman* —Mr A D Hall *Secretary*.—Dr E F Armstrong Professor H E Armstrong, Professor F Keeble, and Dr. E J Russell.	30 0 0
SECTION C —GEOLOGY.		
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation	*Chairman* —Mr R H Tiddeman *Secretary* —Dr A R Dwerryhouse Dr T G Bonney, Mr F W Harmer, Rev S N Harrison, Dr. J Horne, Mr W Lower Carter, Professor W J Sollas, and Messrs W Hill, J W Stather, and J. H Milton	5 0 0
The Investigation of the Igneous and Associated Rocks of Glensaul and Lough Nafooey Areas, Co Galway.	*Chairman* — Professor W W Watts *Secretary* —Professor S H Reynolds. Messrs R G Carruthers and C. I Gardiner	10 0 0
To consider the preparation of a List of Characteristic Fossils	*Chairman* —Professor P F Kendall *Secretary* —Mr W Lower Carter Mr H A Allen, Professor W S Boulton, Professor G Cole, Dr A R Dwerryhouse, Professors J W Gregory, Sir T H Holland, G A Lebour, and S. H. Reynolds, Dr Marie C Stopes, Mr Cosmo Johns, Dr J E Marr, Dr A Vaughan, Professor W W Watts, Mr H Woods, and Dr A. Smith Woodward	5 0 0
The further Exploration of the Upper Old Red Sandstone of Dura Den.	*Chairman* —Dr J. Horne *Secretary* —Dr T J Jehu Messrs H Bolton and A W R Don, Dr J S Flett, Dr B N Peach, Dr R H Traquair, and Dr A. Smith Woodward	75 0 0

1. *Receiving Grants of Money*—continued

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
The Geology of Ramsay Island, Pembrokeshire	*Chairman*—Dr A Strahan *Secretary*—Mr H H Thomas Mr E E L Dixon, Dr J W Evans, and Professor O T Jones	10 0 0
The Old Red Sandstone Rocks of Kiltorcan, Ireland	*Chairman*—Professor Grenville Cole *Secretary*—Professor T Johnson Dr J. W. Evans, Dr R Kidston, and Dr A Smith Woodward	15 0 0

Section D.—ZOOLOGY.

Subject for Investigation, or Purpose	Members of Committee	Grants
To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples	*Chairman*—Professor S J Hickson *Secretary*—Mr E. S Goodrich Sir E. Ray Lankester, Professor A Sedgwick, Professor W C McIntosh, Dr S. F Harmer, Mr G P Bidder, Dr W B Hardy, and Professor A D Waller	30 0 0
To investigate the Biological Problems incidental to the Belmullet Whaling Station	*Chairman*—Dr A E Shipley *Secretary*—Professor J Stanley Gardiner Professor W A Herdman, Rev W Spotswood Green, Mr E S Goodrich, Dr H. W Marett Tims, and Mr R M Barrington	15 0 0
Nomenclator Animalium Genera et Sub-genera	*Chairman*—Dr Chalmers Mitchell *Secretary*—Rev T R R Stebbing Dr M Laurie, Dr Marett Tims, and Dr A Smith Woodward	100 0 0

Section G.—ENGINEERING.

Subject for Investigation, or Purpose	Members of Committee	Grants
The Investigation of Gaseous Explosions, with special reference to Temperature	*Chairman*—Sir W H Preece *Vice-chairman*—Dr Dugald Clerk *Secretary*—Professor W E Dalby Professors W A Bone, F W Burstall, H L Callendar, E G Coker, and H B Dixon, Drs. R T Glazebrook and J A Harker, Colonel H C L Holden, Professors B Hopkinson and J E. Petavel, Captain H Riall Sankey, Professor A Smithells, Professor W Watson, Mr. D L Chapman, and Mr. H E Wimperis	80 0

1 *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s d
	Section H.—ANTHROPOLOGY.	
To investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society	*Chairman* —Dr R. Munro. *Secretary* —Professor W Boyd Dawkins Professor W Ridgeway, Sir Arthur J Evans, Sir C H. Read, Mr H Balfour, and Dr A Bulleid	5 0 0
To conduct Explorations with the object of ascertaining the Age of Stone Circles	*Chairman* —Sir C H Read *Secretary* —Mr H. Balfour Dr G A Auden, Lord Avebury, Professor W Ridgeway, Dr J G Garson, Sir A J Evans, Dr R Munro, Professors Boyd Dawkins and J L Myres, and Mr A L Lewis	2 2 2
To investigate and ascertain the Distribution of Artificial Islands in the lochs of the Highlands of Scotland	*Chairman* —Dr R Munro *Secretary* —Mr A J B Wace Professors T H Bryce, W Boyd Dawkins, J L Myres, and W Ridgeway	5 0 0
To investigate the Physical Characters of the Ancient Egyptians	*Chairman* —Professor G Elliot Smith *Secretary* —Dr F C Shrubsall Dr F Wood Jones, Dr A Keith, and Dr C G Seligmann	34 16 6
To organise Anthropometric Investigations in the British Isles	*Chairman* —Professor A Thomson *Secretary* —Dr F C Shrubsall Dr G A Auden, Dr Duckworth, Professors A Keith and G Elliot Smith	5 0 0
To co-operate with local Committees in Excavations on Roman Sites in Britain	*Chairman* —Professor W Ridgeway *Secretary* —Professor R C Bosanquet Dr T Ashby, Mr Willoughby Gardner and Professor J. L. Myres	15 0 0
To Excavate Early Sites in Macedonia	*Chairman* —Professor W Ridgeway *Secretary* —Professor J L Myres Professor R C Bosanquet and Mr A. J B Wace	30 0 0
To produce certified copies of the Hausa Manuscripts in the possession of Major Tremearne, for deposit in centres at which Hausa is taught and students prepared for the Government Service.	*Chairman* —Mr E Sidney Hartland *Secretary* —Professor J L Myres Mr W Crooke and Major A J N. Tremearne	20 0 0

1 *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s d
SECTION I.—PHYSIOLOGY.		
The Ductless Glands	*Chairman* —Professor Schafer *Secretary* —Professor Swale Vincent Professor A B Macallum, Dr L E Shore, and Mrs W H Thompson	10 0 0
To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman* —Professor S J Hickson *Secretary* —Mr E S Goodrich Sir E Ray Lankester, Professor A Sedgwick, Professor W C McIntosh, Dr S F Harmer, Mr G P Bidder, Dr W B Hardy, and Professor A D Waller	20 0 0
Calorimetric Observations on Man in Health and in Febrile Conditions	*Chairman* —Professor J S Macdonald *Secretary* —Dr Francis A Duffield Dr Keith Lucas	15 0 0
The Dissociation of Oxy Hæmoglobin at High Altitudes.	*Chairman* —Professor E H Starling *Secretary* —Dr J Barcroft Dr W B Hardy	15 0 0
Further Researches on the Structure and Function of the Mammalian Heart	*Chairman* —Professor F Gotch *Secretary* — Professor Stanley Kent	20 0 0
SECTION K.—BOTANY.		
The Structure of Fossil Plants	*Chairman* —Professor F W Oliver *Secretary* —Professor F E Weiss Mr E Newell Arber, Professor A C Seward, and Dr D H Scott	15 0 0
The Investigation of the Jurassic Flora of Yorkshire	*Chairman* —Professor A C Seward *Secretary* —Mr H Hamshaw Thomas Mr H W T Wager and Professor F. E. Weiss	15 0 0
The Investigations of the Flora of the Peat of the Kennet Valley, Berks.	*Chairman* —Professor F Keeble *Secretary* —Miss M C Rayner Professors F W. Oliver and F E. Weiss	15 0 0
The Investigation of the Vegetation of Ditcham Park, Hampshire	*Chairman* — Professor A G Tansley *Secretary* —Mr R S Adamson Dr C. E Moss and Professor R H Yapp	45 0 0

1 *Receiving Grants of Money*—continued

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
Section L.—EDUCATIONAL SCIENCE.		
To inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education	*Chairman*.—Professor J. J. Findlay. *Secretary*.—Professor J. A. Green. Professor J. Adams, Dr. G. A. Auden, Sir E. Brabrook, Dr. W. Brown, Professor E. P. Culverwell, Mr. G. F. Daniell, Miss B. Foxley, Professor R. A. Gregory, Dr. C. W. Kimmins, Professor W. MacDougall, Dr. C. S. Myers, Dr. T. P. Nunn, Dr. W. H. R. Rivers, Dr. F. C. Shrubsall, Mr. H. Bompas Smith, Dr. C. Spearman, and Mr. A. E. Twentyman	20 0 0
The Influence of School Books upon Eyesight	*Chairman*.—Dr. G. A. Auden. *Secretary*.—Mr. G. F. Daniell. Mr. C. H. Bothamley, Mr. W. D. Eggar, Professor R. A. Gregory, Mr. J. L. Holland, Professor Priestley Smith, and Mr. Trevor Walsh.	15 0 0
To inquire into and report on the number, distribution and respective values of Scholarships, Exhibitions and Bursaries held by University Students during their undergraduate course, and on funds private and open available for their augmentation	*Chairman*.—Sir Henry Miers. *Secretary*.—Professor Marcus Hartog. Miss L. J. Clarke, Miss B. Foxley, Professor H. Bompas Smith, and Principal Griffiths	5 0 0
CORRESPONDING SOCIETIES		
Corresponding Societies Committee for the preparation of their Report	*Chairman*.—Mr. W. Whitaker. *Secretary*.—Mr. W. P. D. Stebbing. Rev. J. O. Bevan, Sir Edward Brabrook, Dr. J. G. Garson, Principal E. H. Griffiths, Dr. A. C. Haddon, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Rev. T. R. R. Stebbing, Mr. W. Mark Webb, and the President and General Officers of the Association	25 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee
Section A.—MATHEMATICS AND PHYSICS.	
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements	*Chairman.*—Lord Rayleigh. *Secretary.*—Dr. R. T. Glazebrook. Professors J. Perry and W. G. Adams, Dr. G. Carey Foster, Sir Oliver Lodge, Dr. A. Muirhead, Sir W. H. Preece, Professor A. Schuster, Dr. J. A. Fleming, Professor Sir J. J. Thomson, Dr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Professor S. P. Thompson, Mr. J. Rennie, Principal E. H. Griffiths, Sir Arthur Rücker, Professor H. L. Callendar, and Messrs. G. Matthey, T. Mather, and F. E. Smith.
To aid the work of Establishing a Solar Observatory in Australia	*Chairman.*—Sir David Gill. *Secretary.*—Dr. W. G. Duffield. Rev. A. L. Cortie, Dr. W. J. S. Lockyer, Mr. F. McClean, and Professors A. Schuster and H. H. Turner.
To consider the Nomenclature and Definitions of Magnetic and Electrical Quantities	*Chairman.*—Professor Silvanus Thompson. *Secretary.*—Professor F. G. Baily. Professors H. L. Callendar, J. A. Fleming, and A. Schuster and Mr. F. E. Smith.
Radiotelegraphic Investigations	*Chairman.*—Sir Oliver Lodge. *Secretary.*—Dr. W. H. Eccles. Mr. S. G. Brown, Dr. Erskine Murray, Professors J. A. Fleming, G. W. O. Howe, and H. M. Macdonald, Mr. F. McLean, Capt. H. R. Sankey, and Professor Silvanus Thompson.
Section C.—GEOLOGY.	
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest	*Chairman.*—Professor J. Geikie. *Secretaries.*—Professors W. W. Watts and S. H. Reynolds. Dr. T. Anderson, Mr. G. Bingley, Dr. T. G. Bonney, Mr. C. V. Crook, Professor E. J. Garwood, and Messrs. W. Gray, R. Kidston, A. S. Reid, J. J. H. Teall, R. Welch, W. Whitaker, and H. B. Woodward.
To investigate the Microscopical and Chemical Composition of Charnwood Rocks	*Chairman.*—Professor W. W. Watts. *Secretary.*—Dr. T. T. Groom. Dr. F. W. Bennett and Dr. Stracey.

2. *Not receiving Grants of Money*—continued

Subject for Investigation, or Purpose	Members of Committee
SECTION D.—ZOOLOGY.	
To investigate the Feeding Habits of British Birds by a study of the contents of the crops and gizzards of both adults and nestlings, and by collation of observational evidence, with the object of obtaining precise knowledge as to the economic status of many of our commoner birds affecting rural science	*Chairman*.—Dr A E Shipley *Secretary*.—Mr H S Leigh Messrs J N Halbert, Robert Newstead, Clement Reid, A G L Rogers, and F V Theobald, Professor F E Weiss, Dr C Gordon Hewitt, and Professors S J Hickson, F W Gamble, G H Carpenter, and J Arthur Thomson
To defray expenses connected with work on the Inheritance and Development of Secondary Sexual Characters in Birds	*Chairman*.—Professor G C Bourne *Secretary*.—Mr Geoffrey Smith Mr E S Goodrich, Dr W T Calman, and Dr Marett Tims.
To summon meetings in London or elsewhere for the consideration of matters affecting the interests of Zoology or Zoologists, and to obtain by correspondence the opinion of Zoologists on matters of a similar kind, with power to raise by subscription from each Zoologist a sum of money for defraying current expenses of the Organisation	*Chairman*.—Sir E Ray Lankester *Secretary*.—Professor S J Hickson Professors G C Bourne, J Cossar Ewart, M Hartog, and W A Herdman, Mr M D Hill, Professors J Graham Kerr and Minchin, Dr P Chalmers Mitchell, Professors E B Poulton and A Sedgwick, and Dr A E Shipley
To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth	*Chairman* and *Secretary*.—Professor A Dendy Sir E Ray Lankester, Professor A Sedgwick, Professor Sydney H Vines, and Mr E S Goodrich
To enable Mr Laurie to conduct Experiments in Inheritance	*Chairman*.—Professor W A Herdman *Secretary*.—Mr Douglas Laurie Professor R C Punnett and Dr H W Marett Tims
To formulate a Definite System on which Collectors should record their captures	*Chairman*.—Professor J W H Trail *Secretary*.—Mr F Balfour Browne Drs Scharff and E J Bles, Professors G H Carpenter and E B Poulton, and Messrs A G Tansley and R Lloyd Praeger
A Natural History Survey of the Isle of Man	*Chairman*.—Professor W A Herdman. *Secretary*.—Mr P. M C Kermode Dr W T Calman, Rev J. Davidson, Mr G W Lamplugh, Professor E W. MacBride, and Lord Raglan

2 *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
Section E —GEOGRAPHY	
To inquire into the present state of Geographical Teaching in Scotland	*Chairman* —Dr J Horne *Secretary* —Mr T S Muir Drs R N R Brown and W S Bruce, Messrs G G Chisholm and J Cossar, Professors H N Dickson, P Geddes, and A J. Herbertson, Dr J Scott Keltie, Messrs J Malloch and J McFarlane, and Dr M Newbigin
To inquire into the choice and style of Atlas, Textual, and Wall Maps for School and University Use	*Chairman* —Professor J L Myres. *Secretary* —Rev W J Barton Professors R L Archer and R N R Brown, Mr G G Chisholm, Col C F Close, Professors H N Dickson and A J Herbertson, Mr O J R Howarth, Sir Duncan Johnston, and Messrs T S Muir and E. A Reeves
Section F —ECONOMIC SCIENCE AND STATISTICS	
The Present Condition of the Town Planning Movement and the means by which it can be aided by scientific inquiries, civic and regional surveys, and other methods within the work of the various Sections of the Association	*Chairman* —Professor P Geddes *Secretary* —Mr J H Jones Professor S J Chapman, Mr C R Fay, Professor Gonner, Dr W R Scott and Professor W Smart
Section G —ENGINEERING.	
To report on certain of the more complex Stress Distributions in Engineering Materials	*Chairman* —Professor J Perry *Secretaries* —Professors E G Coker and J E Petavel Professor A Barr, Dr Chas Chree, Mr Gilbert Cook, Professor W E Dalby, Sir J A Ewing, Professor L N G Filon, Messrs A R Fulton and J J Guest, Professors J B Henderson and A E H Love, Mr W Mason, Sir Andrew Noble, Professor K Pearson, Messrs F Rogers and W A Scoble, Dr T E Stanton, and Mr J S Wilson.
Section H —ANTHROPOLOGY.	
The Collection, Preservation and Systematic Registration of Photographs of Anthropological Interest	*Chairman* —Sir C H Read *Secretary* —Mr. E. W Martindell Dr G A Auden, Mr E Heawood, and Professor J L Myres
To conduct Archæological and Ethnological Researches in Crete	*Chairman* —Mr D G Hogarth *Secretary* —Professor J L Myres Professor R C Bosanquet, Dr W L H Duckworth, Sir A J Evans, Professor W Ridgeway, and Dr F C Shrubsall

2. *Not receiving Grants of Money*—continued

Subject for Investigation, or Purpose	Members of Committee
To report on the present state of knowledge of the Prehistoric Civilisation of the Western Mediterranean with a view to future research	*Chairman* —Professor W Ridgeway. *Secretary* —Professor J L Myres Dr T Ashby, Dr W L H Duckworth, Mr D G Hogarth, and Sir A. J Evans
To co-operate with a Local Committee in the excavation of a prehistoric site at Bishop's Stortford	*Chairman* —Professor W Ridgeway *Secretary* —Dr W L H Duckworth Professor W Boyd Dawkins, Dr A C Haddon, Rev Dr A Irving, and Dr. H W Marett Tims
To conduct excavations in Easter Island	*Chairman* —Dr A C Haddon *Secretary* —Dr W. H R Rivers Mr R R Marett and Dr C G Seligmann
To report on Palæolithic Sites in the West of England	*Chairman* —Professor Boyd Dawkins *Secretary* —Dr W L H. Duckworth Professor A. Keith

Section I —PHYSIOLOGY

Subject for Investigation, or Purpose	Members of Committee
Effect of Low Temperature on Cold-blooded Animals	*Chairman* —Professor Swale Vincent *Secretary* —Mr A T Cameron
Electromotive Phenomena in Plants	*Chairman* —Dr A D Waller *Secretary* —Mrs Waller Professors F Gotch, J B Farmer, and Veley, and Dr F O'B Ellison
To acquire further knowledge, Clinical and Experimental, concerning Anæsthetics—especially Chloroform, Ether, and Alcohol—with special reference to Deaths by or during Anæsthesia, and their possible diminution	*Chairman* —Dr A D Waller *Secretary* —Sir F W Hewitt Dr Blumfeld, Mr J A Gardner, and Dr G A Buckmaster
Colour Vision and Colour Blindness	*Chairman* —Professor E H Starling *Secretary* —Dr Edridge-Green Professor F Gotch, Mr Leonard Hill, Professor A W Porter, and Dr A D Waller

Section K —BOTANY

Subject for Investigation, or Purpose	Members of Committee
To consider and report on the advisability and the best means of securing definite Areas for the Preservation of Types of British Vegetation	*Chairman* —Professor F E Weiss *Secretary.*—Mr A G Tansley Professor J W H. Trail, Mr R Lloyd Praeger, Professor F. W Oliver, Professor R W Phillips, Dr C E Moss, and Messrs G C Druce and H W T Wager
To carry out the Scheme for the Registration of Negatives of Botanical Photographs	*Chairman* —Professor F W Oliver *Secretary* —Professor F E Weiss Dr. W G Smith, Mr. A G. Tansley, Dr T. W Woodhead, and Professor R. H Yapp

2 *Not receiving Grants of Money*—continued

Subject for Investigation, or Purpose	Members of Committee
SECTION L.—EDUCATIONAL SCIENCE.	
To take notice of, and report upon changes in, Regulations—whether Legislative, Administrative, or made by Local Authorities — affecting Secondary Education	*Chairman* —Professor H E Armstrong *Secretary* —Major E Gray Miss Coignan, Sir Henry Craik, Principal Griffiths, Dr C W Kimmins, Sir Horace Plunkett, Mr H Ramage, Professor M E Sadler, and Rt Rev. J E C. Welldon
To inquire into the Curricula and Educational Organisation of Industrial and Poor Law Schools with special reference to Day Industrial Schools	*Chairman* —Mr W D Eggar *Secretary* —Mrs W N Shaw Professor R A Gregory, Mr J L Holland, Dr C W Kimmins, and Mr J G Legge.
The Aims and Limits of Examinations	*Chairman* —Professor M E Sadler *Secretary* —Mr P J Hartog Mr D P Berridge, Mr W D Eggar, Professor R A Gregory, Principal E H Griffiths, Miss C L Laurie, Dr W McDougall, Dr T P Nunn, Sir W Ramsay, Rt Rev J E C Welldon, Dr Jessie White, and Mr G U Yule

Communications ordered to be printed in extenso

Section B —Dr J V Eyre Report on Solubility Part 2

Section G —Sir John Macdonald The Road Problem

Resolutions referred to the Council for consideration, and, if desirable, for action

From Section A

That it be recommended to the General Committee that the cordial thanks of the Association be forwarded to the 'Falmouth' Committee for their valuable services since their appointment in 1901, and especially to their Chairman, Sir William Preece, and the Secretaries, Dr R T Glazebrook and Dr W N Shaw

From Section A

That it is desirable that a detailed Magnetic Survey of the British Isles, on the lines of that of Professors Rucker and Thorpe for the epoch of 1891, should now be repeated, in order to answer the question as to the local variations of the terrestrial magnetic elements within twenty-five years

That a representation to this effect be made to the Royal Society, the Admiralty, the Ordnance Survey, and the Meteorological Committee

That, having regard to the importance of the observations at Falmouth in the work of the previous Survey and in other work in connection with terrestrial magnetism and meteorology, steps be taken to assist an appeal for a Treasury Grant, in order that the Observatory at Falmouth may be efficiently maintained

From Section D

That the British Association for the Advancement of Science deplores the rapid destruction of fauna and flora throughout the world, and regards it as an urgent duty that immediate steps should be taken to secure the preservation of all kinds of animals and plants, irrespective of their economic or sporting value.

From Section H

That the copies of the fourth edition of Notes and Queries in Anthropology, now on the point of publication through the Committee appointed for the purpose of its preparation, be delivered as heretofore to the Royal Anthropological Institute for sale to its members and to the public, the proceeds to be reserved at the disposal of the Association towards the expenses of any future editions, and accounts of the sales to be submitted to the General Treasurer of the Association on demand

Synopsis of Grants of Money appropriated for Scientific Purposes by the General Committee at the Dundee Meeting, September 1912. The Names of Members entitled to call on the General Treasurer for the Grants are prefixed to the respective Research Committees.

Section A.—Mathematical and Physical Science.

	£	s.	d.
*Turner, Professor H. H.—Seismological Observations	†60	0	0
*Shaw, Dr. W. N.—Upper Atmosphere	50	0	0
*Ramsay, Sir W.—Grant to the International Commission on Physical and Chemical Constants	40	0	0
*Hill, Professor M. J. M.—Further Tabulation of Bessel and other Functions	30	0	0

Section B.—Chemistry.

*Perkin, Dr. W. H.—Study of Hydro-aromatic Substances	20	0	0
*Armstrong, Professor H. E.—Dynamic Isomerism	30	0	0
*Kipping, Professor F. S.—Transformation of Aromatic Nitro-amines	20	0	0
*Hall, A. D.—Study of Plant Enzymes	30	0	0

Section C.—Geology.

*Tiddeman, R. H.—Erratic Blocks	5	0	0
*Watts, Professor W. W.—Igneous and Associated Rocks of Glensaul, &c.	10	0	0
*Kendall, Professor P. F.—List of Characteristic Fossils	5	0	0
Horne, Dr. J.—Old Red Sandstone of Dura Den	75	0	0
Strahan, Dr. A.—Geology of Ramsay Island, Pembroke	10	0	0
Cole, Professor Grenville—Old Red Sandstone Rocks of Kiltorcan	15	0	0

Section D.—Zoology.

*Hickson, Professor S. J.—Table at the Zoological Station at Naples	30	0	0
*Shipley, Dr. A. E.—Belmullet Whaling Station	15	0	0
Mitchell, Dr. Chalmers.—Nomenclator Animalium	100	0	0

Section G.—Engineering.

*Preece, Sir W. H.—Gaseous Explosions	80	0	0
Carried forward	£625	0	0

* Reappointed.

† In addition, the Council are authorised to expend a sum not exceeding £70 on the printing of circulars, &c., in connection with the Committee on Seismological Observations.

	£	s.	d.
Brought forward	625	0	0

Section H.—Anthropology.

*Munro, Dr. R.—Lake Villages in the neighbourhood of Glastonbury	5	0	0
*Read, C. H.—Age of Stone Circles	2	2	2
*Munro, Dr. R.—Artificial Islands in Highland Lochs	5	0	0
*Smith, Professor G. Elliot.—Physical Characters of the Ancient Egyptians	34	16	6
*Thompson, Professor A.—Anthropometric Investigations in the British Isles .	5	0	0
*Ridgeway, Professor W.—Roman Sites in Britain .	15	0	0
Ridgeway, Professor W. Excavations in Macedonia	30	0	0
Hartland, E. S. Hausa Manuscripts .	20	0	0

Section I.—Physiology.

*Schafer, Professor E. A.—The Ductless Glands .	40	0	0
*Hickson, Professor S. J.—Table at the Zoological Station at Naples .	20	0	0
*Macdonald, Professor J. S.—Calorimetric Observations	45	0	0
*Starling, Professor.—Oxy-Hæmoglobin	15	0	0
Gotch, Professor F.—Mammalian Heart	20	0	0

Section K.—Botany.

*Oliver, Professor F. W.—Structure of Fossil Plants	15	0	0
*Seward, Professor A. C.—Jurassic Flora of Yorkshire	15	0	0
Keeble, Professor F.—Flora of Peat of Kennet Valley	15	0	0
Tansley, A. G.—Vegetation of Ditcham Park	45	0	0

Section L.—Education.

*Findlay, Professor J. J.—Mental and Physical Factors involved in Education . .	20	0	0
*Auden, Dr. G. A.—Influence of School Books on Eyesight	15	0	0
Miers, Sir H.—Scholarships, &c., held by University Students	5	0	0

Corresponding Societies Committee.

*Whitaker, W.—For Preparation of Report ...	25	0	0
Total .	£1,036	18	8

* Reappointed

Annual Meetings, 1913 and 1914.

The Annual Meeting of the Association in 1913 will be held at Birmingham, commencing September 10; in 1914, in Australia.

PRESIDENT'S ADDRESS.

ADDRESS

BY

PROFESSOR E. A. SCHAFER, LL.D., D.Sc., M.D., F.R.S.

PRESIDENT.

Introductory.

It is exactly forty-five years ago—to the day and hour—that the British Association last met in this city and in this hall to listen to a Presidential Address. The President was the Duke of Buccleuch, the General Secretaries, Francis Galton and T. Archer Hirst, the General Treasurer, William Spottiswoode, and the Assistant General Secretary, George Griffith, who was for many years a mainstay of the Association. The Evening Discourses were delivered by John Tyndall 'On Matter and Force,' by Archibald Geikie 'On the Geological Origin of the Scenery of Scotland,' and by Alexander Herschel 'On the Present State of Knowledge regarding Meteors and Meteorites.' The Presidents of Sections, which were then only seven in number, were for Mathematics and Physics, Sir William Thomson—later to be known as Lord Kelvin, for Chemistry, Thomas Anderson, for Geology, Archibald Geikie, who now as President of the Royal Society worthily fills the foremost place in science within the realm, for Biology, William Sharpey, my own revered master, to whose teaching and influence British physiology largely owes the honourable position which it at present occupies, for Geography, Sir Samuel Baker, the African explorer, who with his intrepid wife was the first to follow the Nile to its exit from the Albert Nyanza, for Economic Science, Mr. Grant Duff, and for Mechanical Science, Professor Rankine.

Other eminent men present were Sir David Brewster, J. Clerk Maxwell, Charles Wheatstone, Balfour Stewart, William Crookes, J. B. Lawes and J. H. Gilbert (names inseparable in the history of agricultural science), Crum Brown, G. D. Liveing, W. H. Russell, Alexander Williamson, Henry Alleyne Nicholson, G. J. Allman, John Hutton Balfour, Spencer Cobbold, Anton Dohrn, Sir John Lubbock (now Lord Avebury), William McIntosh, E. Ray Lankester,

C W Peach, William Pengelly, Hughes Bennett, John Cleland, John Davy, Alexander Christison, Alfred Russel Wallace, Allen Thomson William Turner, George Busk, Michael Foster (not yet founder of the Cambridge School of Physiology), Henry Howorth, Sir Roderick Murchison, Clements R Markham, Sir William (afterwards Lord) Armstrong, Sir Charles Lyell, and Douglas Galton Many of those enumerated have in the course of nature passed away from us, but not a few remain, and we are glad to know that most of these retain their ancient vigour in spite of the five-and-forty years which separate us from the last meeting in this place

Selection of Subject of Address.

For the Address with which it is usual for the President to open the proceedings of the annual assembly, the field covered by the aims of the British Association provides the widest possible range of material from which to select One condition alone is prescribed by custom, viz , that the subject chosen shall lie within the bounds of those branches of knowledge which are dealt with in the Sections There can be no ground of complaint regarding this limitation on the score of variety, for within the forty years that I have myself been present (not, I regret to say, without a break) at these gatherings, problems relating to the highest mathematics on the one hand, and to the most utilitarian applications of science on the other, with every possible gradation between these extremes, have been discussed before us by successive Presidents, and the addition from time to time of new Sections (one of which, that of Agriculture, we welcome at this Meeting) enables the whilom occupant of this chair to traverse paths which have not been previously trodden by his predecessors On the last two occasions, under the genial guidance of Professors Bonney and Sir William Ramsay, we have successively been taken in imagination to the glaciers which flow between the highest peaks of the Alps and into the bowels of the earth; where we were invited to contemplate the prospective disappearance of the material upon which all our industrial prosperity depends Needless to say that the lessons to be drawn from our visits to those unaccustomed levels were placed before us with all the eloquence with which these eminent representatives of Geology and Chemistry are gifted It is fortunately not expected that I should be able to soar to such heights or to plunge to such depths, for the branch of science with which I am personally associated is merely concerned with the investigation of the problems of living beings, and I am able to invite you to remain for an hour or so at the level of ordinary mortality to consider certain questions which at any rate cannot fail to have an immediate interest for every one present, seeing that they deal with the nature, origin, and maintenance of life

Everybody knows, or thinks he knows, what life is; at least, we are

all acquainted with its ordinary, obvious manifestations It would, therefore, seem that it should not be difficult to find an exact definition The quest has nevertheless baffled the most acute thinkers Herbert Spencer devoted two chapters of his 'Principles of Biology' to the discussion of the attempts at definition which had up to that date been proposed, and himself suggested another But at the end of it all he is constrained to admit that no expression had been found which would embrace all the known manifestations of animate, and at the same time exclude those of admittedly inanimate, objects

Definition.

The ordinary dictionary definition of life is 'the state of living' Dastre, following Claude Bernard, defines it as 'the sum total of the phenomena common to all living beings'[1] Both of these definitions are, however, of the same character as Sydney Smith's definition of an archdeacon as 'a person who performs archdiaconal functions' I am not myself proposing to take up your time by attempting to grapple with a task which has proved too great for the intellectual giants of philosophy, and I have the less disposition to do so because recent advances in knowledge have suggested the probability that the dividing line between animate and inanimate matter is less sharp than it has hitherto been regarded, so that the difficulty of finding an inclusive definition is correspondingly increased

As a mere word 'life' is interesting in the fact that it is one of those abstract terms which has no direct antithesis, although probably most persons would regard 'death' in that light A little consideration will show that this is not the case 'Death' implies the pre-existence of 'life', there are physiological grounds for regarding death as a phenomenon of life—it is the completion, the last act of life We cannot speak of a non-living object as *possessing* death in the sense that we speak of a living object as *possessing* life The adjective 'dead' is, it is true, applied in a popular sense antithetically to objects which have never possessed life, as in the proverbial expression 'as dead as a door-nail' But in the strict sense such application is not justifiable, since the use of the terms dead and living implies either in the past or in the present the possession of the recognised properties of living matter On the other hand, the expressions *living* and *lifeless*, *animate* and *inanimate*, furnish terms which are undoubtedly antithetical Strictly and literally, the words animate and inanimate express the presence or absence of 'soul', and not infrequently we find the terms 'life' and 'soul' erroneously employed as if identical But it is hardly necessary for me to state that the remarks I have to make regarding 'life' must not be taken to apply to the conception to which the word 'soul' is attached

Life not identical with soul.

[1] *La vie et la mort*, English translation by W J Greenstreet, 1911, p 54

The fact that the formation of such a conception is only possible in connection with life, and that the growth and elaboration of the conception has only been possible as the result of the most complex processes of life in the most complex of living organisms, has doubtless led to a belief in the identity of life with soul But unless the use of the expression ' soul ' is extended to a degree which would deprive it of all special significance, the distinction between these terms must be strictly maintained For the problems of life are essentially problems of matter, we cannot conceive of life in the scientific sense as existing apart from matter. The phenomena of life are investigated, and can only be investigated, by the same methods as all other phenomena of matter, and the general results of such investigations tend to show that living beings are governed by laws identical with those which govern inanimate matter The more we study the manifestations of life the more we become convinced of the truth of this statement and the less we are disposed to call in the aid of a special and unknown form of energy to explain those manifestations

Problems of life are problems of matter.

The most obvious manifestation of life is ' spontaneous ' movement We see a man, a dog, a bird move, and we know that they are alive. We place a drop of pond water under the microscope, and see numberless particles rapidly moving within it; we affirm that it swarms with ' life ' We notice a small mass of clear slime changing its shape, throwing out projections of its structureless substance, creeping from one part of the field of the microscope to another We recognise that the slime is living, we give it a name—*Amœba limax*—the slug amœba We observe similar movements in individual cells of our own body, in the white corpuscles of our blood, in connective tissue cells, in growing nerve cells, in young cells everywhere We denote the similarity between these movements and those of the amœba by employing the descriptive term ' amœboid ' for both We regard such movements as indicative of the possession of ' life ', nothing seems more justifiable than such an inference

Phenomena indicative of life: Movement.

But physicists[2] show us movements of a precisely similar character in substances which no one by any stretch of imagination can regard as living, movements of oil drops, of organic and inorganic mixtures, even of mercury globules, which are indistinguishable in their character from those of the living organisms we have been studying movements which can only be described by the same term amœboid, yet obviously produced as the result of purely physical and chemical reactions causing changes in surface tension of the fluids under exami-

Similarity of movements in living and non-living matter.

[2] G Quincke, *Annal. d. Physik u. Chem.* 1870 and 1888

nation.[3] It is therefore certain that such movements are not specifically 'vital,' that their presence does not necessarily denote 'life' And when we investigate closely even such active movements as those of a vibratile cilium or a phenomenon so closely identified with life as the contraction of a muscle, we find that these present so many analogies with amœboid movements as to render it certain that they are fundamentally of the same character and produced in much the same manner[4] Nor can we for a moment doubt that the complex actions which are characteristic of the more highly differentiated organisms have been developed in the course of evolution from the simple movements characterising the activity of undifferentiated protoplasm, movements which can themselves, as we have seen, be perfectly imitated by non-living material The chain of evidence regarding this particular manifestation of life—movement—is complete Whether exhibited as the amœboid movement of the proteus animalcule or of the white corpuscle of our blood, as the ciliary motion of the infusorian or of the ciliated cell, as the contraction of a muscle under the governance of the will, or as the throbbing of the human heart responsive to every emotion of the mind, we cannot but conclude that it is alike subject to and produced in conformity with the general laws of matter, by agencies resembling those which cause movements in lifeless material[5]

It will perhaps be contended that the resemblances between the movements of living and non-living matter may be only superficial, and that the conclusion regarding their identity to which we are led will be dissipated when we endeavour to penetrate more deeply into the working of living substance For can we not recognise along with the possession of movement the presence of other phenomena which are equally characteristic of life and with which non-living material is not endowed? Prominent among the characteristic phenomena of life are the processes of assimilation and disassimilation, the taking in of food and its elabora-

Assimilation and disassimilation.

[3] The causation not only of movements but of various other manifestations of life by alterations in surface tension of living substance is ably dealt with by A B Macallum in a recent article in Asher and Spiro's *Ergebnisse der Physiologie*, 1911 Macallum has described an accumulation of potassium salts at the more active surfaces of the protoplasm of many cells, and correlates this with the production of cell-activity by the effect of such accumulation upon the surface tension. The literature of the subject will be found in this article

[4] G F FitzGerald (*Brit Assoc Reports*, 1898, and *Scient Trans Roy. Dublin Society*, 1898) arrived at this conclusion with regard to muscle from purely physical considerations

[5] 'Vital spontaneity, so readily accepted by persons ignorant of biology, is disproved by the whole history of science Every vital manifestation is a response to a stimulus, a provoked phenomenon It is unnecessary to say this is also the case with brute bodies, since that is precisely the foundation of the great principle of the inertia of matter It is plain that it is also as applicable to living as to inanimate matter.'—Dastre, *op cit.*, p. 280.

tion[6] These, surely, it may be thought, are not shared by matter which is not endowed with life Unfortunately for this argument, similar processes occur characteristically in situations which no one would think of associating with the presence of life A striking example of this is afforded by the osmotic phenomena presented by solutions separated from one another by semipermeable films, a condition precisely similar to that which is constantly found in living matter[7]

Chemical phenomena accompanying life.

It is not so long ago that the chemistry of organic matter was thought to be entirely different from that of inorganic substances But the line between inorganic and organic chemistry, which up to the middle of the last century appeared sharp, subsequently became misty and has now disappeared Similarly the chemistry of living organisms, which is now a recognised branch of organic chemistry, but used to be considered as so much outside the domain of the chemist that it could only be dealt with by those whose special business it was to study 'vital' processes, is passing every day more out of the hands of the biologist and into those of the pure chemist

The colloid constitution of living matter. Identity of physical and chemical processes in living and non-living matter.

Somewhat more than half a century ago Thomas Graham published his epoch-making observations relating to the properties of matter in the colloidal state observations which are proving all-important in assisting our comprehension of the properties of living substance For it is becoming every day more apparent that the chemistry and physics of the living organism are essentially the chemistry and physics of nitrogenous colloids Living substance or protoplasm always, in fact, takes the form of a colloidal solution In this solution the colloids are associated with crystalloids (electrolytes), which are either free in the solution or attached to the molecules of the colloids Surrounding and enclosing the living substance thus constituted of both colloid and crystalloid material is a film, probably also formed of colloid, but which may have a lipoid substratum associated with it (Overton). This film serves the purpose of an osmotic membrane, permitting of exchanges by diffusion between the colloidal solution constituting the protoplasm

[6] The terms 'assimilation' and 'disassimilation' express the physical and chemical changes which occur within protoplasm as the result of the intake of nutrient material from the circumambient medium and its ultimate transformation into waste products which are passed out again into that medium, the whole cycle of these changes being embraced under the term 'metabolism'

[7] Leduc (*The Mechanism of Life*, English translation by W Deane Butcher, 1911) has given many illustrations of this statement In the Report of the meeting of 1867 in Dundee is a paper by Dr J D Heaton (On Simulations of Vegetable Growths by Mineral Substances) dealing with the same class of phenomena See also J Hall Edwards, Address to the Birmingham and Midland Inst, Nov, 1911 The conditions of osmosis in cells have been especially studied by Hamburger (*Osmotischer Druck und Ionenlehre*, Wiesbaden, 1902-4),

and the circumambient medium in which it lives. Other similar films or membranes occur in the interior of protoplasm These films have in many cases specific characters, both physical and chemical, thus favouring the diffusion of special kinds of material into and out of the protoplasm and from one part of the protoplasm to another. It is the changes produced under these physical conditions, associated with those caused by active chemical agents formed within protoplasm and known as *enzymes*, that effect assimilation and disassimilation Quite similar changes can be produced outside the body (*in vitro*) by the employment of methods of a purely physical and chemical nature It is true that we are not yet familiar with all the intermediate stages of transformation of the materials which are taken in by a living body into the materials which are given out from it But since the initial processes and the final results are the same as they would be on the assumption that the changes are brought about in conformity with the known laws of chemistry and physics, we may fairly conclude that all changes in living substance are brought about by ordinary chemical and physical forces

Similarity of the processes of growth and reproduction in living and non-living matter.

Should it be contended that growth and reproduction are properties possessed only by living bodies and constitute a test by which we may differentiate between life and non-life, between the animate and inanimate creation, it must be replied that no contention can be more fallacious Inorganic crystals grow and multiply and reproduce their like, given a supply of the requisite pabulum In most cases for each kind of crystal there is, as with living organisms, a limit of growth which is not exceeded, and further increase of the crystalline matter results not in further increase in size but in multiplication of similar crystals Leduc has shown that the growth and division of artificial colloids of an inorganic nature, when placed in an appropriate medium, present singular resemblances to the phenomena of the growth and division of living organisms Even so complex a process as the division of a cell-nucleus by karyokinesis as a preliminary to the multiplication of the cell by division—a phenomenon which would *primâ facie* have seemed and has been commonly regarded as a distinctive manifestation of the life of the cell—can be imitated with solutions of a simple inorganic salt, such as chloride of sodium, containing a suspension of carbon particles, which arrange and rearrange themselves under the influence of the movements of the electrolytes in a manner indistinguishable from that adopted by the particles of chromatin in a dividing nucleus And in the process of sexual reproduction, the researches of J Loeb and others upon the ova of the sea-urchin have proved that we can no longer consider such an apparently vital phenomenon as the fertilisation of the egg as being the result of living

material brought to it by the spermatozoon, since it is possible to start the process of division of the ovum and the resulting formation of cells, and ultimately of all the tissues and organs—in short, to bring about the development of the whole body—if a simple chemical reagent is substituted for the male element in the process of fertilisation Indeed, even a mechanical or electrical stimulus may suffice to start development *Kurz und gut*, as the Germans say, vitalism as a working hypothesis has not only had its foundations undermined, but most of the superstructure has toppled over, and if any difficulties of explanation still persist, we are justified in assuming that the cause is to be found in our imperfect knowledge of the constitution and working of living material At the best vitalism explains nothing, and the term 'vital force' is an expression of ignorance which can bring us no further along the path of knowledge Nor is the problem in any way advanced by substituting for the term 'vitalism' 'neo-vitalism,' and for 'vital force' 'biotic energy'[8] 'New presbyter is but old priest writ large'

The question of vitalism and vital force.

Further, in its chemical composition we are no longer compelled to consider living substance as possessing infinite complexity, as was thought to be the case when chemists first began to break up the proteins of the body into their simpler constituents The researches of Miescher, which have been continued and elaborated by Kossel and his pupils, have acquainted us with the fact that a body so important for the nutritive and reproductive functions of the cell as the nucleus—which may be said indeed to represent the quintessence of cell-life—possesses a chemical constitution of no very great complexity; so that we may even hope some day to see the material which composes it prepared synthetically And when we consider that the nucleus is not only itself formed of living substance, but is capable of causing other living substance to be built up, is, in fact, the directing agent in all the principal chemical changes which take place within the living cell, it must be admitted that we are a long step forward in our knowledge of the chemical basis of life That it is the *form* of nuclear matter rather than its chemical and molecular structure which is the important factor in nuclear activity cannot be supposed The form of nuclei, as every microscopist knows, varies infinitely, and there are numerous living organisms in which the nuclear matter is without form, appearing simply as granules distributed in the protoplasm Not that the form assumed and the transformations undergone by the nucleus are without import-

The possibility of the synthesis of living matter.

[8] B Moore, in *Recent Advances in Physiology*, 1906; Moore and Roaf, *ibid*; and *Further Advances in Physiology*, 1909 Moore lays especial stress on the transformations of energy which occur in protoplasm. See on the question of vitalism Gley (*Revue Scientifique*, 1911) and D'Arcy Thompson (Address to Section D at Portsmouth, 1911).

ance; but it is none the less true that even in an amorphous condition the material which in the ordinary cell takes the form of a 'nucleus' may, in simpler organisms which have not in the process of evolution become complete cells, fulfil functions in many respects similar to those fulfilled by the nucleus of the more differentiated organism.

A similar anticipation regarding the probability of eventual synthetic production may be made for the proteins of the cell-substance Considerable progress in this direction has indeed already been made by Emil Fischer, who has for many years been engaged in the task of building up the nitrogenous combinations which enter into the formation of the complex molecule of protein It is satisfactory to know that the significance of the work both of Fischer and of Kossel in this field of biological chemistry has been recognised by the award to each of these distinguished chemists of a Nobel prize

The elements composing living substance are few in number Those which are constantly present are carbon, hydrogen, oxygen, and nitrogen.

The chemical constitution of living substance.

With these, both in nuclear matter and also, but to a less degree, in the more diffuse living material which we know as protoplasm, phosphorus is always associated 'Ohne Phosphor kein Gedank' is an accepted aphorism, 'Ohne Phosphor kein Leben' is equally true Moreover, a large proportion, rarely less than 70 per cent, of water appears essential for any manifestation of life, although not in all cases necessary for its continuance, since organisms are known which will bear the loss of the greater part if not the whole of the water they contain without permanent impairment of their vitality The presence of certain inorganic salts is no less essential, chief amongst them being chloride of sodium and salts of calcium, magnesium, potassium, and iron The combination of these elements into a colloidal compound represents the chemical basis of life, and when the chemist succeeds in building up this compound it will without doubt be found to exhibit the phenomena which we are in the habit of associating with the term 'life' [9]

The above considerations seem to point to the conclusion that the possibility of the production of life—*i e*, of living material—is not so remote as has been generally assumed

Source of life. The possibility of spontaneous generation.

Since the experiments of Pasteur, few have ventured to affirm a belief in the spontaneous generation of bacteria and monads and other micro-organisms, although before his time this was by many believed to be of universal occurrence My esteemed friend Dr Charlton Bastian is, so far as I am aware, the only scientific man of eminence who still adheres to the old creed, and Dr Bastian, in spite of numerous experiments and the publication of many

[9] The most recent account of the chemistry of protoplasm is that by Botazzi (Das Cytoplasma u die Korpersäfte) in Winterstein's *Handb. d. vergl Physiologie*, Bd. I., 1912. The literature is given in this article.

books and papers, has not hitherto succeeded in winning over any converts to his opinion. I am myself so entirely convinced of the accuracy of the results which Pasteur obtained—are they not within the daily and hourly experience of everyone who deals with the sterilisation of organic solutions?—that I do not hesitate to believe, if living torulae or mycelia are exhibited to me in flasks which had been subjected to prolonged boiling after being hermetically sealed, that there has been some fallacy either in the premisses or in the carrying out of the operation. The appearance of organisms in such flasks would not furnish to my mind proof that they were the result of spontaneous generation Assuming no fault in manipulation or fallacy in observation, I should find it simpler to believe that the germs of such organisms have resisted the effects of prolonged heat than that they became generated spontaneously If spontaneous generation is possible, we cannot expect it to take the form of living beings which show so marked a degree of differentiation, both structural and functional, as the organisms which are described as making their appearance in these experimental flasks [10] Nor should we expect the spontaneous generation of living substance of any kind to occur in a fluid the organic constituents of which have been so altered by heat that they can retain no sort of chemical resemblance to the organic constituents of living matter. If the formation of life—of living substance—is possible at the present day—and for my own part I see no reason to doubt it—a boiled infusion of organic matter—and still less of inorganic matter—is the last place in which to look for it. Our mistrust of such evidence as has yet been brought forward need not, however, preclude us from admitting the possibility of the formation of living from non-living substance [11]

Setting aside, as devoid of scientific foundation, the idea of immediate

[10] It is fair to point out that Dr. Bastian suggests that the formation of ultramicroscopic living particles may precede the appearance of the microscopic organisms which he describes *The Origin of Life*, 1911, p 65.

[11] The present position of the subject is succinctly stated by Dr Chalmers Mitchell in his article on 'Abiogenesis' in the *Encyclopædia Britannica* Dr Mitchell adds · 'It may be that in the progress of science it may yet be possible to construct living protoplasm from non-living material The refutation of abiogenesis has no further bearing on this possibility than to make it probable that if protoplasm ultimately be formed in the laboratory, it will be by a series of steps, the earlier steps being the formation of some substance, or substances, now unknown, which are not protoplasm Such intermediate stages may have existed in the past.' And Huxley in his Presidential Address at Liverpool in 1870 says 'But though I cannot express this conviction' (*i e*, of the impossibility of the occurrence of abiogenesis, as exemplified by the appearance of organisms in hermetically sealed and sterilised flasks) 'too strongly, I must carefully guard myself against the supposition that I intend to suggest that no such thing as abiogenesis ever has taken place in the past or ever will take place in the future With organic chemistry, molecular physics and physiology yet in their infancy and every day making prodigious strides, I think it would be the height of presumption for any man to say that the conditions under which matter assumes the properties we call "vital" may not, some day, be artificially brought together.'

supernatural intervention in the first production of life, we are not only justified in believing, but compelled to believe, that living matter must have owed its origin to causes similar in character to those which have been instrumental in producing all other forms of matter in the universe; in other words, to a process of gradual evolution [12] But it has been customary of late amongst biologists to shelve the investigation of the mode of origin of life by evolution from non-living matter by relegating its solution to some former condition of the earth's history, when, it is assumed, opportunities were accidentally favourable for the passage of inanimate matter into animate; such opportunities, it is also assumed, having never since recurred and being never likely to recur [13]

Life a product of evolution.

Various eminent scientific men have even supposed that life has not actually originated upon our globe, but has been brought to it from another planet or from another stellar system Some of my audience may still remember the controversy that was excited when the theory of the origin of terrestrial life by the intermediation of a meteorite was propounded by Sir William Thomson in his Presidential Address at the meeting of this Association in Edinburgh in 1871. To this 'meteorite' theory [14] the apparently fatal objection was raised that it would take some sixty million years for a meteorite to travel from the nearest stellar system to our earth and it is inconceivable that any kind of life could be maintained during such a period Even from the nearest planet 150 years would be necessary, and the heating of the meteorite in passing through our atmosphere and at its impact with the earth would, in all probability, destroy any life which might have existed within it A cognate theory, that of *cosmic panspermia*, assumes that life may exist and may have existed indefinitely in cosmic dust in the interstellar spaces (Richter, 1865; Cohn, 1872), and may with this dust fall slowly to the earth without undergoing the heating which is experienced by a meteorite Arrhenius,[15] who adopts this theory, states that if living germs were carried through the ether by luminous and other radiations the time necessary for their transportation from our globe to the nearest stellar system would be only nine thousand years, and to Mars only twenty days!

[12] The arguments in favour of this proposition have been arrayed by Meldola in his Herbert Spencer Lecture, 1910, pp 16-24 Meldola leaves the question open whether such evolution has occurred only in past years or is also taking place now He concludes that whereas certain carbon compounds have survived by reason of possessing extreme stability, others—the precursors of living matter—survived owing to the possession of extreme lability and adaptability to variable conditions of environment A similar suggestion was previously made by Lockyer, *Inorganic Evolution*, 1900, pp. 169, 170.

[13] T H Huxley, Presidential Address, 1870; A B Macallum, 'On the Origin of Life on the Globe,' in *Trans Canadian Institute*, VIII

[14] First suggested, according to Dastre, by de Salles-Guyon (Dastre, *op cit*, p 252) The theory received the support of Helmholtz

[15] *Worlds in the Making*, transl by H Borns, chap viii, p 221, 1908.

But the acceptance of such theories of the arrival of life on the earth does not bring us any nearer to a conception of its actual mode of origin, on the contrary it merely serves to banish the investigation of the question to some conveniently inaccessible corner of the universe and leaves us in the unsatisfactory position of affirming not only that we have no knowledge as to the mode of origin of life—which is unfortunately true—but that we never can acquire such knowledge—which it is to be hoped is not true [16] Knowing what we know, and believing what we believe, as to the part played by evolution in the development of terrestrial matter, we are, I think (without denying the possibility of the existence of life in other parts of the universe [17]) justified in regarding these cosmic theories as inherently improbable—at least in comparison with the solution of the problem which the evolutionary hypothesis offers [18]

The evolutionary hypothesis as applied to the origin of life.

I assume that the majority of my audience have at least a general idea of the scope of this hypothesis, the general acceptance of which has within the last sixty years altered the whole aspect not only of biology, but of every other branch of natural science, including astronomy, geology, physics, and chemistry [19] To those who have not this familiarity I would recommend the perusal of a little book by Professor Judd entitled 'The Coming of Evolution,' which has recently appeared as one of the Cambridge manuals I know of no similar book in which the subject is as clearly and succinctly treated Although the author nowhere expresses the opinion that the actual origin of life on the earth has arisen by evolution from non-living matter, it is impossible to read either this or any similar exposition in which the essential unity of the evolutionary process is insisted upon

[16] 'The history of science shows how dangerous it is to brush aside mysteries —i e, unsolved problems—and to interpose the barrier placarded "eternal—no thoroughfare" '—R Meldola, Herbert Spencer Lecture, 1910

[17] Some authorities, such as Errera, contend, with much probability, that the conditions in interstellar space are such that life, as we understand it, could not possibly exist there

[18] As Verworn points out, such theories would equally apply to the origin of any other chemical combination, whether inorganic or organic, which is met with on our globe, so that they lead directly to absurd conclusions —*Allgemeine Physiologie*, 1911

[19] As Meldola insists, this general acceptance was in the first instance largely due to the writings of Herbert Spencer 'We are now prepared for evolution in every domain . As in the case of most great generalisations, thought had been moving in this direction for many years Lamarck and Buffon had suggested a definite mechanism of organic development, Kant and Laplace a principle of celestial evolution, while Lyell had placed geology upon an evolutionary basis The principle of continuity was beginning to be recognised in physical science . It was Spencer who brought these independent lines of thought to a focus, and who was the first to make any systematic attempt to show that the law of development expressed in its widest and most abstract form was universally followed throughout cosmical processes, inorganic, organic, and superorganic.'—*Op. cit*, p. 14.

without concluding that the origin of life must have been due to the same process, this process being, without exception, continuous, and admitting of no gap at any part of its course Looking therefore at the evolution of living matter by the light which is shed upon it from the study of the evolution of matter in general, we are led to regard it as having been produced, not by a sudden alteration, whether exerted by natural or supernatural agency, but by a gradual process of change from material which was lifeless, through material on the borderland between inanimate and animate, to material which has all the characteristics to which we attach the term 'life' So far from expecting a sudden leap from an inorganic, or at least an unorganised, into an organic and organised condition, from an entirely inanimate substance to a completely animate state of being, should we not rather expect a gradual procession of changes from inorganic to organic matter, through stages of gradually increasing complexity until material which can be termed living is attained? And in place of looking for the production of fully formed living organisms in hermetically sealed flasks, should we not rather search Nature herself, under natural conditions, for evidence of the existence, either in the past or in the present, of transitional forms between living and non-living matter?

The difficulty, nay the impossibility, of obtaining evidence of such evolution from the past history of the globe is obvious Both the hypothetical transitional material and the living material which was originally evolved from it may, as Macallum has suggested, have taken the form of diffused ultra-microscopic particles of living substance [20], and even if they were not diffused but aggregated into masses, these masses could have been physically nothing more than colloidal watery slime which would leave no impress upon any geological formation Myriads of years may have elapsed before some sort of skeleton in the shape of calcareous or siliceous spicules began to evolve itself, and thus enabled 'life,' which must already have possessed a prolonged existence, to make any sort of geological record It follows that in attempting to pursue the evolution of living matter to its beginning in terrestrial history we can only expect to be confronted with a blank wall of nescience

The problem would appear to be hopeless of ultimate solution, if we are rigidly confined to the supposition that the evolution of life has only occurred once in the past history of the globe But are we justified in assuming that at one period only, and as it were by a fortunate and fortuitous concomitation of substance and circumstance, living matter became evolved out of non-living matter—life became

[20] There still exist in fact forms of life which the microscope cannot show us (E A Minchin, Presidential Address to Quekett Club, 1911), and germs which are capable of passing through the pores of a Chamberland filter.

established? Is there any valid reason to conclude that at some previous period of its history our earth was more favourably circumstanced for the production of life than it is now?[21] I have vainly sought for such reason, and if none be forthcoming the conclusion forces itself upon us that the evolution of non-living into living substance has happened more than once—and we can be by no means sure that it may not be happening still

It is true that up to the present there is no evidence of such happening: no process of transition has hitherto been observed But on the other hand, is it not equally true that the kind of evidence which would be of any real value in determining this question has not hitherto been looked for? We may be certain that if life is being produced from non-living substance it will be life of a far simpler character than any that has yet been observed—in material which we shall be uncertain whether to call animate or inanimate, even if we are able to detect it at all, and which we may not be able to visualise physically even after we have become convinced of its existence [22] But we can look with the mind's eye and follow in imagination the transformation which non-living matter may have undergone and may still be undergoing to produce living substance No principle of evolution is better founded than that insisted upon by Sir Charles Lyell, justly termed by Huxley 'the greatest geologist of his time,' that we must interpret the past history of our globe by the present, that we must seek for an explanation of what has happened by the study of what is happening, that, given similar circumstances, what has occurred at one time will probably occur at another The process of evolution is universal The inorganic materials of the globe are continually undergoing transition New chemical combinations are constantly being formed and old ones broken up, new elements are making their appearance and old elements disappearing [23] Well may we ask ourselves why the production of living matter alone should be subject to other laws than those which have produced, and are producing, the various forms of non-living matter, why what has happened may not happen? If living matter has been evolved from lifeless in the past, we are justified in accepting the

[21] Chalmers Mitchell (Article 'Life,' *Encycl Brit*, eleventh edition) writes as follows. 'It has been suggested from time to time that conditions very unlike those now existing were necessary for the first appearance of life, and must be repeated if living matter is to be reconstituted artificially No support for such a view can be derived from observations of the existing conditions of life'

[22] 'Spontaneous generation of life could only be perceptually demonstrated by filling in the long terms of a series between the complex forms of inorganic and the simplest forms of organic substance Were this done, it is quite possible that we should be unable to say (especially considering the vagueness of our definitions of life) where life began or ended'—K Pearson, *Grammar of Science*, second edition, 1900, p 350

[23] See on the production of elements, W Crookes, Address to Section B, Brit Assoc, 1886, T Preston, *Nature*, vol lx, p 180, J J Thomson, *Phil Mag*, 1897, p 311, Norman Lockyer, *op cit*, 1900, G Darwin, Pres Addr Brit Assoc 1905

conclusion that its evolution is possible in the present and in the future. Indeed, we are not only justified in accepting this conclusion, we are forced to accept it When or where such change from non-living to living matter may first have occurred, when or where it may have continued, when or where it may still be occurring, are problems as difficult as they are interesting, but we have no right to assume that they are insoluble

Since living matter always contains water as its most abundant constituent, and since the first living organisms recognisable as such in the geological series were aquatic, it has generally been assumed that life must first have made its appearance in the depths of the ocean.[24] Is it, however, certain that the assumption that life originated in the sea is correct? Is not the land-surface of our globe quite as likely to have been the nidus for the evolutionary transformation of non-living into living material as the waters which surround it? Within this soil almost any chemical transformation may occur, it is subjected much more than matters dissolved in sea-water to those fluctuations of moisture, temperature, electricity, and luminosity which are potent in producing chemical changes But whether life, in the form of a simple slimy colloid, originated in the depths of the sea or on the surface of the land, it would be equally impossible for the geologist to trace its beginnings, and were it still becoming evolved in the same situations, it would be almost as impossible for the microscopist to follow its evolution We are therefore not likely to obtain direct evidence regarding such a transformation of non-living into living matter in Nature, even if it is occurring under our eyes

An obvious objection to the idea that the production of living matter from non-living has happened more than once is that, had this been the case, the geological record should reveal more than one palæontological series This objection assumes that evolution would in every case take an exactly similar course and proceed to the same goal—an assumption which is, to say the least, improbable If, as might well be the case, in any other palæontological series than the one with which we are acquainted the process of evolution of living beings did not proceed beyond Protista, there would be no obvious geological evidence regarding it, such evidence would only be discoverable by a carefully directed search made with that particular object in view [25] I would not by any

[24] For arguments in favour of the first appearance of life having been in the sea, see A B Macallum, 'The Palæochemistry of the Ocean,' *Trans Canad Instit*, 1903-4

[25] Lankester (Art 'Protozoa,' Encycl Brit, tenth edition) conceives that the first protoplasm fed on the antecedent steps in its own evolution F J Allen (*Brit. Assoc. Reports,* 1896) comes to the conclusion that living substance is probably constantly being produced, but that this fails to make itself evident owing to the substance being seized and assimilated by existing organisms. He believes that 'in accounting for the first origin of life on this earth it is not

means minimise the difficulties which attend the suggestion that the evolution of life may have occurred more than once or may still be happening, but on the other hand, it must not be ignored that those which attend the assumption that the production of life has occurred once only are equally serious Indeed, had the idea of the possibility of a multiple evolution of living substance been first in the field, I doubt if the prevalent belief regarding a single fortuitous production of life upon the globe would have become established among biologists—so much are we liable to be influenced by the impressions we receive in scientific childhood!

Further course of evolution of life.

Assuming the evolution of living matter to have occurred—whether once only or more frequently matters not for the moment—and in the form suggested, viz , as a mass of colloidal slime possessing the property of assimilation and therefore of growth, reproduction would follow as a matter of course For all material of this physical nature—fluid or semi-fluid in character—has a tendency to undergo subdivision when its bulk exceeds a certain size The subdivision may be into equal or nearly equal parts, or it may take the form of buds In either case every separated part would resemble the parent in chemical and physical properties, and would equally possess the property of taking in and assimilating suitable material from its liquid environment, growing in bulk and reproducing its like by subdivision *Omne vivum e vivo* In this way from any beginning of living material a primitive form of life would spread, and would gradually people the globe The establishment of life being once effected, all forms of organisation follow under the inevitable laws of evolution *Ce n'est que le premier pas qui coûte*

We can trace in imagination the segregation of a more highly phosphorised portion of the primitive living matter, which we may now consider to have become more akin to the protoplasm of organisms with which we are familiar. This more phosphorised portion might not for myriads of generations take the form of a definite nucleus, but it would be composed of material having a composition and qualities similar to those of the nucleus of a cell Prominent among these qualities is that of catalysis—the function of effecting profound chemical changes in other material in contact with it without itself undergoing permanent change This catalytic function may have been exercised directly by the living substance or may have been carried

necessary that, as Pfluger assumed, the planet should have been at a former period a glowing fire-ball' He 'prefers to believe that the circumstances which support life would also favour its origin' And elsewhere 'Life is not an extraordinary phenomenon, not even an importation from some other sphere, but rather the actual outcome of circumstances on this earth.'

on through the agency of the enzymes already mentioned, which are also of a colloid nature but of simpler constitution than itself, and which differ from the catalytic agents employed by the chemist in the fact that they produce their effects at a relatively low temperature In the course of evolution special enzymes would become developed for adaptation to special conditions of life, and with the appearance of these and other modifications, a process of differentiation of primitive living matter into individuals with definite specific characters gradually became established We can conceive of the production in this way from originally undifferentiated living substance of simple differentiated organisms comparable to the lowest forms of Protista But how long it may have taken to arrive at this stage we have no means of ascertaining To judge from the evidence afforded by the evolution of higher organisms it would seem that a vast period of time would be necessary for even this amount of organisation to establish itself

Formation of the nucleated cell

The next important phase in the process of evolution would be the segregation and moulding of the diffused or irregularly aggregated nuclear matter into a definite nucleus around which all the chemical activity of the organism will in future be centred Whether this change were due to a slow and gradual process of segregation or of the nature of a jump, such as Nature does occasionally make, the result would be the advancement of the living organism to the condition of a complete nucleated cell a material advance not only in organisation but—still more important—in potentiality for future development Life is now embodied in the cell, and every living being evolved from this will itself be either a cell or a cell-aggregate *Omnis cellula e cellulâ*

Establishment of sexual differences.

After the appearance of a nucleus—but how long after it is impossible to conjecture—another phenomenon appeared upon the scene in the occasional exchange of nuclear substance between cells In this manner became established the process of sexual reproduction. Such exchange in the unicellular Protista might and may occur between any two cells forming the species, but in the multicellular Metazoa it became—like other functions—specialised in particular cells The result of the exchange is rejuvenescence, associated with an increased tendency to subdivide and to produce new individuals This is due to the introduction of a stimulating or catalytic chemical agent into the cell which is to be rejuvenated, as is proved by the experiments of Loeb already alluded to It is true that the chemical material introduced into the germ-cell in the ordinary process of its fertilisation by the sperm-cell is usually accompanied by the introduction of definite morphological elements which blend with others already contained within the germ-cell, and it is believed that the transmission of such morphological ele-

ments of the parental nuclei is related to the transmission of parental qualities But we must not be blind to the possibility that these transmitted qualities may be connected with specific chemical characters of the transmitted elements, in other words, that heredity also is one of the questions the eventual solution of which we must look to the chemist to provide.

So far we have been chiefly considering life as it is found in the simplest forms of living substance, organisms for the most part entirely microscopic and neither distinctively animal nor vegetable, which were grouped together by Haeckel as a separate kingdom of animated nature—that of Protista.

Aggregate life.

But persons unfamiliar with the microscope are not in the habit of associating the term 'life' with microscopic organisms, whether these take the form of cells or of minute portions of living substance which have not yet attained to that dignity We most of us speak and think of life as it occurs in ourselves and other animals with which we are familiar, and as we find it in the plants around us We recognise it in these by the possession of certain properties—movement, nutrition, growth, and reproduction We are not aware by intuition, nor can we ascertain without the employment of the microscope, that we and all the higher living beings, whether animal or vegetable, are entirely formed of aggregates of nucleated cells, each microscopic and each possessing its own life Nor could we suspect by intuition that what we term our life is not a single indivisible property, capable of being blown out with a puff like the flame of a candle, but is the aggregate of the lives of many millions of living cells of which the body is composed It is but a short while ago that this cell-constitution was discovered it occurred within the lifetime, even within the memory, of some who are still with us What a marvellous distance we have travelled since then in the path of knowledge of living organisms! The strides which were made in the advance of the mechanical sciences during the nineteenth century, which is generally considered to mark that century as an age of unexampled progress, are as nothing in comparison with those made in the domain of biology, and their interest is entirely dwarfed by that which is aroused by the facts relating to the phenomena of life which have accumulated within the same period And not the least remarkable of these facts is the discovery of the cell-structure of plants and animals!

Let us consider how cell-aggregates came to be evolved from organisms consisting of single cells Two methods are possible—viz (1) the adhesion of a number of originally separate individuals; (2) the subdivision of a single individual without the products of its subdivision breaking loose from one another No doubt this last is the manner whereby the

Evolution of the cell-aggregate.

cell-aggregate was originally formed, since it is that by which it is still produced, and we know that the life-history of the individual is an epitome of that of the species. Such aggregates were in the beginning solid; the cells in contact with one another and even in continuity: subsequently a space or cavity became formed in the interior of the mass, which was thus converted into a hollow sphere. All the cells of the aggregate were at first perfectly similar in structure and in function; there was no subdivision of labour. All would take part in effecting locomotion, all would receive stimuli from outside, all would take in and digest nutrient matter, which would then be passed into the cavity of the sphere to serve as a common store of nourishment. Such organisms are still found, and constitute the lowest types of Metazoa. Later one part of the hollow sphere became dimpled to form a cup, the cavity of the sphere became correspondingly altered in shape. With this change in structure differentiation of function between the cells covering the outside and those lining the inside of the cup made its appearance. Those on the outside subserved locomotor functions and received and transmitted from cell to cell stimuli, physical or chemical, received by the organism, while those on the inside, being freed from such functions, tended to specialise in the direction of the inception and digestion of nutrient material, which, passing from them into the cavity of the invaginated sphere, served for the nourishment of all the cells composing the organism. The further course of evolution produced many changes of form and ever-increasing complexity of the cavity thus produced by simple invagination. Some of the cell-aggregates settled down to a sedentary life, becoming plant-like in appearance and to some extent in habit. Such organisms, complex in form but simple in structure, are the Sponges. Their several parts are not, as in the higher Metazoa, closely interdependent: the destruction of any one part, however extensive, does not either immediately or ultimately involve death of the rest; all parts function separately, although doubtless mutually benefiting by their conjunction, if only by slow diffusion of nutrient fluid throughout the mass. There is already some differentiation in these organisms, but the absence of a nervous system prevents any general co-ordination, and the individual cells are largely independent of one another.

Our own life, like that of all the higher animals, is an *aggregate life*, the life of the whole is the life of the individual cells. The life of some of these cells can be put an end to, the rest may continue to live. This is, in fact, happening every moment of our lives. The cells which cover the surface of our body, which form the scarf-skin and the hairs and nails, are constantly dying and the dead cells are rubbed off or cut away, their place being taken by others supplied from living layers beneath. But the death of these cells does not

affect the vitality of the body as a whole. They serve merely as a protection, or an ornamental covering, but are otherwise not material to our existence On the other hand, if a few cells, such as those nerve-cells under the influence of which respiration is carried on, are destroyed or injured, within a minute or two the whole living machine comes to a standstill, so that to the bystander the patient is dead, even the doctor will pronounce life to be extinct. But this pronouncement is correct only in a special sense What has happened is that, owing to the cessation of respiration, the supply of oxygen to the tissues is cut off And since the manifestations of life cease without this supply, the animal or patient appears to be dead If, however, within a short period we supply the needed oxygen to the tissues requiring it, all the manifestations of life reappear

It is only some cells which lose their vitality at the moment of so-called 'general death' Many cells of the body retain their individual life under suitable circumstances long after the rest of the body is dead Notable among these are muscle-cells McWilliam showed that the muscle-cells of the blood-vessels give indications of life several days after an animal has been killed The muscle-cells of the heart in mammals have been revived and caused to beat regularly and strongly many hours after apparent death In man this result has been obtained by Kuliabko as many as eighteen hours after life had been pronounced extinct in animals after days have elapsed Waller has shown that indications of life can be elicited from various tissues many hours and even days after general death Sherrington observed the white corpuscles of the blood to be active when kept in a suitable nutrient fluid weeks after removal from the blood-vessels A French histologist, Jolly, has found that the white corpuscles of the frog, if kept in a cool place and under suitable conditions, show at the end of a year all the ordinary manifestations of life Carrell and Burrows have observed activity and growth to continue for long periods in the isolated cells of a number of tissues and organs kept under observation in a suitable medium Carrell has succeeded in substituting entire organs obtained after death from one animal for those of another of the same species, and has thereby opened up a field of surgical treatment the limit of which cannot yet be descried It is a well-established fact that any part of the body can be maintained alive for hours isolated from the rest if perfused with serum (Kronecker, frog-heart), or with an oxygenated solution of salts in certain proportions (Ringer) Such revival and prolongation of the life of separated organs is an ordinary procedure in laboratories of physiology Like all the other instances enumerated, it is based on the fact that the individual cells of an organ have a life of their own which is largely independent, so that they will continue in suitable circumstances to live, although the rest of the body to which they belonged may be dead

But some cells, and the organs which are formed of them, are more necessary to maintain the life of the aggregate than others, on account of the nature of the functions which have become specialised in them This is the case with the nerve-cells of the respiratory centre, since they preside over the movements which are necessary to effect oxygenation of the blood It is also true for the cells which compose the heart, since this serves to pump oxygenated blood to all other cells of the body without such blood most cells soon cease to live Hence we examine respiration and heart to determine if life is present: when one or both of these are at a standstill we know that life cannot be maintained These are not the only organs necessary for the maintenance of life, but the loss of others can be borne longer, since the functions which they subserve, although useful or even essential to the organism, can be dispensed with for a time The life of some cells is therefore more, of others less, necessary for maintaining the life of the rest On the other hand, the cells composing certain organs have in the course of evolution ceased to be necessary, and their continued existence may even be harmful Wiedersheim has enumerated more than a hundred of these organs in the human body Doubtless Nature is doing her best to get rid of them for us, and our descendants will some day have ceased to possess a vermiform appendix or a pharyngeal tonsil. until that epoch arrives we must rely for their removal on the more rapid methods of surgery!

The maintenance of the life of the cell-aggregate in the higher animals. Co-ordinating mechanisms.

We have seen that in the simplest multicellular organisms, where one cell of the aggregate differs but little from another, the conditions for the maintenance of the life of the whole are nearly as simple as those for individual cells. But the life of a cell-aggregate such as composes the bodies of the higher animals is maintained not only by the conditions for the maintenance of the life of the individual cell being kept favourable, but also by the co-ordination of the varied activities of the cells which form the aggregate Whereas in the lowest Metazoa all cells of the aggregate are alike in structure and function and perform and share everything in common, in higher animals (and for that matter in the higher plants also) the cells have become specialised, and each is only adapted for the performance of a particular function Thus the cells of the gastric glands are only adapted for the secretion of gastric juice, the cells of the villi for the absorption of digested matters from the intestine, the cells of the kidney for the removal of waste products and superfluous water from the blood, those of the heart for pumping blood through the vessels Each of these cells has its individual life and performs its individual functions But unless there were some sort of co-operation and subordination to the needs of the body generally, there would be sometimes too little,

sometimes too much gastric juice secreted; sometimes too tardy, sometimes too rapid an absorption from the intestine; sometimes too little, sometimes too much blood pumped into the arteries, and so on As the result of such lack of co-operation the life of the whole would cease to be normal and would eventually cease to be maintained

We have already seen what are the conditions which are favourable for the maintenance of life of the individual cell, no matter where situated The principal condition is that it must be bathed by a nutrient fluid of suitable and constant composition In higher animals this fluid is the lymph, which bathes the tissue elements and is itself constantly supplied with fresh nutriment and oxygen by the blood Some tissue-cells are directly bathed by blood, and in invertebrates, in which there is no special system of lymph-vessels, all the tissues are thus nourished All cells both take from and give to the blood, but not the same materials or to an equal extent. Some, such as the absorbing cells of the villi, almost exclusively give, others, such as the cells of the renal tubules, almost exclusively take Nevertheless, the resultant of all the give and take throughout the body serves to maintain the composition of the blood constant under all circumstances In this way the first condition of the maintenance of the life of the aggregate is fulfilled by insuring that the life of the individual cells composing it is kept normal

The second essential condition for the maintenance of life of the cell-aggregate is the co-ordination of its parts and the due regulation of their activity, so that they may work together for the benefit of the whole In the animal body this is effected in two ways first, through the nervous system, and second, by the action of specific chemical substances which are formed in certain organs and carried by the blood to other parts of the body, the cells of which they excite to activity These substances have received the general designation of ' hormones ' (*ὁρμάω*, to stir up), a term introduced by Professor Starling Their action, and indeed their very existence, has only been recognised of late years, although the part which they play in the physiology of animals appears to be only second in importance to that of the nervous system itself, indeed, maintenance of life may become impossible in the absence of certain of these hormones

Part played by the nervous system in the maintenance of aggregate life.

Before we consider the manner in which the nervous system serves to co-ordinate the life of the cell-aggregate, let us see how it has become evolved

Evolution of a nervous system.

The first step in the process was taken when certain of the cells of the external layer became specially sensitive to stimuli from outside, whether caused by mechanical impressions (tactile and auditory stimuli) or impressions of light and darkness (visual stimuli) or chemical impressions The effects of such impressions were probably at first simply

communicated to adjacent cells and spread from cell to cell throughout the mass. An advance was made when the more impressionable cells threw out branching feelers amongst the other cells of the organism. Such feelers would convey the effects of stimuli with greater rapidity and directness to distant parts. They may at first have been retractile, in this respect resembling the long pseudopodia of certain Rhizopoda. When they became fixed they would be potential nerve-fibres and would represent the beginning of a nervous system. Even yet (as Ross Harrison has shown), in the course of development of nerve-fibres, each fibre makes its appearance as an amœboid cell-process which is at first retractile, but gradually grows into the position it is eventually to occupy and in which it will become fixed.

In the further course of evolution a certain number of these specialised cells of the external layer sank below the general surface, partly perhaps for protection, partly for better nutrition; they became nerve-cells. They remained connected with the surface by a prolongation which became an afferent or sensory nerve-fibre, and through its termination between the cells of the general surface continued to receive the effects of external impressions; on the other hand, they continued to transmit these impressions to other, more distant cells by their efferent prolongations. In the further course of evolution the nervous system thus laid down became differentiated into distinct *afferent*, *efferent*, and *intermediary* portions. Once established, such a nervous system, however simple, must dominate the organism, since it would furnish a mechanism whereby the individual cells would work together more effectually for the mutual benefit of the whole.

It is the development of the nervous system, although not proceeding in all classes along exactly the same lines, which is the most prominent feature of the evolution of the Metazoa. By and through it all impressions reaching the organism from the outside are translated into contraction or some other form of cell-activity. Its formation has been the means of causing the complete divergence of the world of animals from the world of plants, none of which possess any trace of a nervous system. Plants react, it is true, to external impressions, and these impressions produce profound changes and even comparatively rapid and energetic movements in parts distant from the point of application of the stimulus—as in the well-known instance of the sensitive plant. But the impressions are in all cases propagated directly from cell to cell—not through the agency of nerve-fibres; and in the absence of anything corresponding to a nervous system it is not possible to suppose that any plant can ever acquire the least glimmer of intelligence. In animals, on the other hand, from a slight original modification of certain cells has directly proceeded in the course of evolution the elaborate structure of the nervous system with all its varied and complex func-

tions, which reach their culmination in the workings of the human intellect. 'What a piece of work is a man! How noble in reason! How infinite in faculty! In form and moving how express and admirable! In action how like an angel! In apprehension how like a god!' But lest he be elated with his psychical achievements, let him remember that they are but the result of the acquisition by a few cells in a remote ancestor of a slightly greater tendency to react to an external stimulus, so that these cells were brought into closer touch with the outer world; while on the other hand, by extending beyond the circumscribed area to which their neighbours remained restricted, they gradually acquired a dominating influence over the rest. These dominating cells became nerve-cells, and now not only furnish the means for transmission of impressions from one part of the organism to another, but in the progress of time have become the seat of perception and conscious sensation, of the formation and association of ideas, of memory, volition, and all the manifestations of the mind!

Regulation of movements by the nervous system. Voluntary movements.

The most conspicuous part played by the nervous system in the phenomena of life is that which produces and regulates the general movements of the body—movements brought about by the so-called voluntary muscles. These movements are actually the result of impressions imparted to sensory or afferent nerves at the periphery—*e.g.*, in the skin or in the several organs of special sense; the effect of these impressions may not be immediate, but can be stored for an indefinite time in certain cells of the nervous system. The regulation of movements—whether they occur instantly after reception of the peripheral impression or result after a certain lapse of time, whether they are accompanied by conscious sensation or are of a purely reflex and unconscious character—is an intricate process, and the conditions of their co-ordination are of a complex nature involving not merely the causation of contraction of certain muscles, but also the prevention of contraction of others. For our present knowledge of these conditions we are largely indebted to the researches of Professor Sherrington.

Involuntary movements.

A less conspicuous but no less important part played by the nervous system is that by which the contractions of involuntary muscles are regulated. Under normal circumstances these are always independent of consciousness, but their regulation is brought about in much the same way as is that of the contractions of voluntary muscles—viz., as the result of impressions received at the periphery. These are transmitted by afferent fibres to the central nervous system, and from the latter other impulses are sent down, mostly along the nerves of the sympathetic or autonomic system of nerves, which either stimulate or prevent contraction of the involun-

tary muscles Many involuntary muscles have a natural tendency to continuous or rhythmic contraction which is quite independent of the central nervous system; in this case the effect of impulses received from the latter is merely to increase or diminish the amount of such contraction An example of this double effect is observed in connection with the heart, which—although it can contract regularly and rhythmically when cut off from the nervous system and even if removed from the body—is normally stimulated to increased activity by impulses coming from the central nervous system through the sympathetic, or to diminished activity by others coming through the vagus It is due to the readiness by which the action of the heart is influenced in these opposite ways by the spread of impulses generated during the nerve-storms which we term 'emotions' that in the language of poetry, and even of every day, the word 'heart' has become synonymous with the emotions themselves

Effects of emotions.

The involuntary muscle of the arteries has its action similarly balanced When its contraction is increased, the size of the vessels is lessened and they deliver less blood, the parts they supply accordingly become pale in colour On the other hand, when the contraction is diminished the vessels enlarge and deliver more blood, the parts which they supply become correspondingly ruddy These changes in the arteries, like the effects upon the heart, may also be produced under the influence of emotions Thus 'blushing' is a purely physiological phenomenon due to diminished action of the muscular tissue of the arteries, whilst the pallor produced by fright is caused by an increased contraction of that tissue Apart, however, from these conspicuous effects, there is constantly proceeding a less apparent but not less important balancing action between the two sets of nerve-fibres distributed to heart and blood-vessels, which are influenced in one direction or another by every sensation which we experience and even by impressions of which we may be wholly unconscious, such as those which occur during sleep or anæsthesia, or which affect our otherwise insensitive internal organs

A further instance of nerve-regulation is seen in secreting glands Not all glands are thus regulated, at least not directly, but in those which are, the effects are striking Their regulation is of the same general nature as that exercised upon involuntary muscle, but it influences the chemical activities of the gland-cells and the outpouring of secretion from them By means of this regulation a secretion can be produced or arrested, increased or diminished As with muscle, a suitable balance is in this way maintained, and the activity of the glands is adapted to the requirements of the organism Most of the digestive glands are

Regulation of secretion by the nervous system.

thus influenced, as are the skin-glands which secrete sweat And by the action of the nervous system upon the skin-glands, together with its effect in increasing or diminishing the blood-supply to the cutaneous blood-vessels, the temperature of our blood is regulated and is kept at the point best suited for maintenance of the life and activity of the tissues

Regulation of body temperature.

The action of the nervous system upon the secretion of glands is strikingly exemplified, as in the case of its action upon the heart and blood-vessels by the effects of the emotions Thus an emotion of one kind—such as the anticipation of food—will cause saliva to flow—'the mouth to water', whereas an emotion of another kind—such as fear or anxiety—will stop the secretion, causing the 'tongue to cleave unto the roof of the mouth,' and rendering speech difficult or impossible Such arrest of the salivary secretion also makes the swallowing of dry food difficult advantage of this fact is taken in the 'ordeal by rice' which used to be employed in the East for the detection of criminals

Effects of emotions on secretion.

The activities of the cells constituting our bodies are controlled, as already mentioned, in another way than through the nervous system, viz, by chemical agents (hormones) circulating in the blood Many of these are produced by special glandular organs, known as internally secreting glands The ordinary secreting glands pour their secretions on the exterior of the body or on a surface communicating with the exterior, the internally secreting glands pass the materials which they produce directly into the blood In this fluid the hormones are carried to distant organs Their influence upon an organ may be essential to the proper performance of its functions or may be merely ancillary to it In the former case removal of the internally secreting gland which produces the hormone, or its destruction by disease, may prove fatal to the organism This is the case with the suprarenal capsules small glands which are adjacent to the kidneys, although having no physiological connection with these organs A Guy's physician, Dr Addison, in the middle of the last century showed that a certain affection, almost always fatal, since known by his name, is associated with disease of the suprarenal capsules A short time after this observation a French physiologist, Brown-Séquard, found that animals from which the suprarenal capsules are removed rarely survive the operation for more than a few days In the concluding decade of the last century interest in these bodies was revived by the discovery that they are constantly yielding to the blood a chemical agent (or hormone) which stimulates the contractions of the heart and arteries and assists in the promotion of every action which is brought about through the sympathetic nervous

Regulation by chemical agents: hormones. Internal secretions.

Suprarenals.

system (Langley) In this manner the importance of their integrity has been explained, although we have still much to learn regarding their functions

Another instance of an internally secreting gland which is essential to life, or at least to its maintenance in a normal condition, is the

Thyroid.

thyroid The association of imperfect development or disease of the thyroid with disorders of nutrition and inactivity of the nervous system is well ascertained The form of idiocy known as cretinism and the affection termed myxœdema are both associated with deficiency of its secretion somewhat similar conditions to these are produced by the surgical removal of the gland The symptoms are alleviated or cured by the administration of its juice On the other hand, enlargement of the thyroid, accompanied by increase of its secretion, produces symptoms of nervous excitation, and similar symptoms are caused by excessive administration of the glandular substance by the mouth From these observations it is inferred that the juice contains hormones which help to regulate the nutrition of the body and serve to stimulate the nervous system, for the higher functions of which they appear to be essential To quote M Gley, to whose researches we owe much of our knowledge regarding the functions of this organ 'La genèse et l'exercice des plus hautes facultés de l'homme sont conditionnés par l'action purement chimique d'un produit de sécrétion Que les psychologues méditent ces faits! '

The case of the parathyroid glandules is still more remarkable These organs were discovered by Sandstrom in 1880 They are four

Parathyroids

minute bodies, each no larger than a pin's head, imbedded in the thyroid Small as they are, their internal secretion possesses hormones which exert a powerful influence upon the nervous system If they are completely removed, a complex of symptoms, technically known as 'tetany,' is liable to occur, which is always serious and may be fatal Like the hormones of the thyroid itself, therefore, those of the parathyroids produce effects upon the nervous system, to which they are carried by the blood, although the effects are of a different kind

Another internally secreting gland which has evoked considerable interest during the last few years is the pituitary body This is a small

Pituitary.

structure no larger than a cob-nut attached to the base of the brain It is mainly composed of glandular cells Its removal has been found (by most observers) to be fatal—often within two or three days Its hypertrophy, when occurring during the general growth of the body, is attended by an undue development of the skeleton, so that the stature tends to assume gigantic proportions When the hypertrophy occurs after growth is completed, the extremities—viz., the hands and feet, and the bones of the face—are mainly affected; hence

the condition has been termed 'acromegaly' (enlargement of extremities) The association of this condition with affections of the pituitary was pointed out in 1885 by a distinguished French physician, Dr. Pierre Marie Both 'giants' and 'acromegalists' are almost invariably found to have an enlarged pituitary. The enlargement is generally confined to one part—the anterior lobe—and we conclude that this produces hormones which stimulate the growth of the body generally and of the skeleton in particular The remainder of the pituitary is different in structure from the anterior lobe and has a different function From it hormones can be extracted which, like those of the suprarenal capsule, although not exactly in the same manner, influence the contraction of the heart and arteries Its extracts are also instrumental in promoting the secretion of certain glands When injected into the blood they cause a free secretion of water from the kidneys and of milk from the mammary glands, neither of which organs are directly influenced (as most other glands are) through the nervous system Doubtless under natural conditions these organs are stimulated to activity by hormones which are produced in the pituitary and which pass from this into the blood

The internally secreting glands which have been mentioned (thyroid, parathyroid, suprarenal, pituitary) have, so far as is known, no other function than that of producing chemical substances of this character for the influencing of other organs, to which they are conveyed by the blood It is interesting to observe that these glands are all of very small size, none being larger than a walnut, and some—the parathyroids—almost microscopic In spite of this, they are essential to the proper maintenance of the life of the body, and the total removal of any of them by disease or operation is in most cases speedily fatal.

Pancreas.

There are, however, organs in the body yielding internal secretions to the blood in the shape of hormones, but exercising at the same time other functions A striking instance is furnished by the pancreas, the secretion of which is the most important of the digestive juices This—the pancreatic juice—forms the external secretion of the gland, and is poured into the intestine, where its action upon the food as it passes out from the stomach has long been recognised It was, however, discovered in 1889 by von Mering and Minkowski that the pancreas also furnishes an internal secretion, containing a hormone which is passed from the pancreas into the blood, by which it is carried first to the liver and afterwards to the body generally This hormone is essential to the proper utilisation of carbohydrates in the organism It is well known that the carbohydrates of the food are converted into grape sugar and circulate in this form in the blood, which always contains a certain amount, the blood conveys it to all the cells of the body, and they utilise it as fuel If, owing to disease of the pan-

creas or as the result of its removal by surgical procedure, its internal secretion is not available, sugar is no longer properly utilised by the cells of the body and tends to accumulate in the blood; from the blood the excess passes off by the kidneys, producing diabetes.

Duodenum.

Another instance of an internal secretion furnished by an organ which is devoted largely to other functions is the 'pro-secretin' found in the cells lining the duodenum When the acid gastric juice comes into contact with these cells it converts their pro-secretin into 'secretin' This is a hormone which is passed into the blood and circulates with that fluid It has a specific effect on the externally secreting cells of the pancreas, and causes the rapid outpouring of pancreatic juice into the intestine This effect is similar to that of the hormones of the pituitary body upon the cells of the kidney and mammary gland It was discovered by Bayliss and Starling

Internal secretions of the reproductive organs.

The reproductive glands furnish in many respects the most interesting example of organs which—besides their ordinary products, the germ- and sperm-cells (ova and spermatozoa)—form hormones which circulate in the blood and effect changes in cells of distant parts of the body It is through these hormones that the secondary sexual characters, such as the comb and tail of the cock, the mane of the lion, the horns of the stag, the beard and enlarged larynx of a man, are produced, as well as the many differences in form and structure of the body which are characteristic of the sexes The dependence of these so-called secondary sexual characters upon the state of development of the reproductive organs has been recognised from time immemorial, but has usually been ascribed to influences produced through the nervous system, and it is only in recent years that the changes have been shown to be brought about by the agency of internal secretions and hormones, passed from the reproductive glands into the circulating blood [26]

Chemical nature of hormones.

It has been possible in only one or two instances to prepare and isolate the hormones of the internal secretions in a sufficient condition of purity to subject them to analysis, but enough is known about them to indicate that they are organic bodies of a not very complex nature, far simpler than proteins and even than enzymes Those which have been studied are all dialysable, are readily soluble in water but insoluble in alcohol, and are not destroyed by boiling One at least—that of the medulla of the suprarenal capsule—has been prepared synthetically, and when their

[26] The evidence is to be found in F. H. A Marshall, *The Physiology of Reproduction*, 1911.

exact chemical nature has been somewhat better elucidated it will probably not be difficult to obtain others in the same way

From the above it is clear that not only is a co-ordination through the nervous system necessary in order that life shall be maintained in a normal condition, but a chemical co-ordination is no less essential These may be independent of one another, but on the other hand they may react upon one another For it can be shown that the production of some at least of the hormones is under the influence of the nervous system (Biedl, Asher, Elliott), whilst, as we have seen, some of the functions of the nervous system are dependent upon hormones

Time will not permit me to refer in any but the briefest manner to the protective mechanisms which the cell aggregate has evolved for its defence against disease, especially disease produced by parasitic micro-organisms These, which belong with few exceptions to the Protista, are without doubt the most formidable enemies which the multicellular Metazoa, to which all the higher animal organisms belong, have to contend against To such micro-organisms are due *inter alia* all diseases which are liable to become epidemic, such as anthrax and rinderpest in cattle, distemper in dogs and cats, small-pox, scarlet fever, measles, and sleeping sickness in man The advances of modern medicine have shown that the symptoms of these diseases—the disturbances of nutrition, the temperature, the lassitude or excitement, and other nervous disturbances—are the effects of chemical poisons (*toxins*) produced by the micro-organisms and acting deleteriously upon the tissues of the body The tissues, on the other hand, endeavour to counteract these effects by producing other chemical substances destructive to the micro-organisms or antagonistic to their action these are known as *anti-bodies* Sometimes the protection takes the form of a subtle alteration in the living substance of the cells which renders them for a long time, or even permanently, insusceptible (immune) to the action of the poison Sometimes certain cells of the body, such as the white corpuscles of the blood, eat the invading micro-organisms and destroy them bodily by the action of chemical agents within their protoplasm The result of an illness thus depends upon the result of the struggle between these opposing forces—the micro-organisms on the one hand and the cells of the body on the other—both of which fight with chemical weapons If the cells of the body do not succeed in destroying the invading organisms it is certain that the invaders will in the long run destroy them, for in this combat no quarter is given Fortunately we have been able, by the aid of animal experimentation, to acquire some knowledge of the manner in which we are attacked by micro-organisms and of the methods which the cells of our body

Protective chemical mechanisms. Toxins and antitoxins.

adopt to repel the attack, and the knowledge is now extensively utilised to assist our defence. For this purpose protective serums or antitoxins, which have been formed in the blood of other animals, are employed to supplement the action of those which our own cells produce. It is not too much to assert that the knowledge of the parasitic origin of so many diseases and of the chemical agents which on the one hand cause, and on the other combat, their symptoms, has transformed medicine from a mere art practised empirically into a real science based upon experiment. The transformation has opened out an illimitable vista of possibilities in the direction not only of cure, but, more important still, of prevention. It has taken place within the memory of most of us who are here present. And only last February the world was mourning the death of one of the greatest of its benefactors—a former President of this Association[27]—who, by applying this knowledge to the practice of surgery, was instrumental, even in his own lifetime, in saving more lives than were destroyed in all the bloody wars of the nineteenth century!

Parasitic nature of diseases.

The question has been debated whether, if all accidental modes of destruction of the life of the cell could be eliminated, there would remain a possibility of individual cell-life, and even of aggregate cell-life, continuing indefinitely; in other words, Are the phenomena of senescence and death a natural and necessary sequence to the existence of life? To most of my audience it will appear that the subject is not open to debate But some physiologists (*e g* , Metchnikoff) hold that the condition of senescence is itself abnormal, that old age is a form of disease or is due to disease. and, theoretically at least, is capable of being eliminated We have already seen that individual cell-life, such as that of the white blood-corpuscles and of the cells of many tissues, can under suitable conditions be prolonged for days or weeks or months after general death Unicellular organisms kept under suitable conditions of nutrition have been observed to carry on their functions normally for prolonged periods and to show no degeneration such as would accompany senescence. They give rise by division to others of the same kind, which also, under favourable conditions, continue to live, to all appearance indefinitely But these instances, although they indicate that in the simplest forms of organisation existence may be greatly extended without signs of decay, do not furnish conclusive evidence of indefinite prolongation of life Most of the cells which constitute the body, after a period of growth and activity, sometimes more, sometimes less prolonged, eventually undergo atrophy and cease to perform satisfactorily the

Senescence and death.

[27] Lord Lister was President at Liverpool in 1896

functions which are allotted to them. And when we consider the body as a whole, we find that in every case the life of the aggregate consists of a definite cycle of changes which, after passing through the stages of growth and maturity, always leads to senescence, and finally terminates in death The only exception is in the reproductive cells, in which the processes of maturation and fertilisation result in rejuvenescence, so that instead of the usual downward change towards senescence, the fertilised ovum obtains a new lease of life, which is carried on into the new-formed organism The latter again itself ultimately forms reproductive cells, and thus the life of the species is continued It is only in the sense of its propagation in this way from one generation to another that we can speak of the indefinite continuance of life we can only be immortal through our descendants!

Average duration of life and possibility of its prolongation.

The individuals of every species of animal appear to have an average duration of existence [28] Some species are known the individuals of which live only for a few hours, whilst others survive for a hundred years [29] In man himself the average length of life would probably be greater than the three-score and ten years allotted to him by the Psalmist if we could eliminate the results of disease and accident, when these results are included it falls far short of that period If the terms of life given in the purely mythological part of the Old Testament were credible, man would in the early stages of his history have possessed a remarkable power of resisting age and disease But, although many here present were brought up to believe in their literal veracity, such records are no longer accepted even by the most orthodox of theologians, and the nine hundred odd years with which Adam and his immediate descendants are credited, culminating in the nine hundred and sixty-nine of Methuselah, have been relegated, with the account of Creation and the Deluge, to their proper position in literature When we come to the Hebrew Patriarchs, we notice a considerable diminution to have taken place in what the insurance offices term the 'expectation of life' Abraham is described as having lived only to 175 years, Joseph and Joshua to 110, Moses to 120, even at that age 'his eye was not dim nor his natural force abated' We cannot say that under ideal conditions all these terms are impossible; indeed, Metchnikoff is disposed to regard them as probable; for great ages are still occasionally recorded, although it is doubtful if any as considerable as these are ever substantiated That the expectation of life was

[28] This was regarded by Buffon as related to the period of growth, but the ratio is certainly not constant The subject is discussed by Ray Lankester in an early work *On Comparative Longevity in Man and Animals*, 1870

[29] The approximately regular periods of longevity of different species of animals furnishes a strong argument against the theory that the decay of old age is an accidental phenomenon, comparable with disease.

better then than now would be inferred from the apologetic tone adopted by Jacob when questioned by Pharaoh as to his age · 'The days of the years of my pilgrimage are a hundred and thirty years; few and evil have the days of the years of my life been, and have not attained unto the days of the years of the life of my fathers in the days of their pilgrimage ' David, to whom, before the advent of the modern statistician, we owe the idea that seventy years is to be regarded as the normal period of life,[30] is himself merely stated to have 'died in a good old age ' The periods recorded for the Kings show a considerable falling-off as compared with the Patriarchs, but not a few were cut off by violent deaths, and many lived lives which were not ideal Amongst eminent Greeks and Romans few very long lives are recorded, and the same is true of historical persons in mediæval and modern history. It is a long life that lasts much beyond eighty; three such linked together carry us far back into history Mankind is in this respect more favoured than most mammals, although a few of these surpass the period of man's existence [31] Strange that the brevity of human life should be a favourite theme of preacher and poet when the actual term of his 'erring pilgrimage ' is greater than that of most of his fellow-creatures!

The end of life.

The modern applications of the principles of preventive medicine and hygiene are no doubt operating to lengthen the average life But even if the ravages of disease could be altogether eliminated, it is certain that at any rate the fixed cells of our body must eventually grow old and ultimately cease to function, when this happens to cells which are essential to the life of the organism, general death must result This will always remain the universal law, from which there is no escape 'All that lives must die, passing through nature to eternity '

Such natural death unaccelerated by disease—is not death by disease as unnatural as death by accident?—should be a quiet, painless phenomenon, unattended by violent change As Dastre expresses it, 'The need of death should appear at the end of life, just as the need of sleep appears at the end of the day.' The change has been led gradually up to by an orderly succession of phases, and is itself the last manifestation of life Were we all certain of a quiet passing—were we sure that there would be 'no moaning of the bar when we go out to sea '—we could anticipate the coming of death after a ripe old age without apprehension And if ever the time shall arrive when man will have learned to regard this change as a simple physiological process, as natural as

[30] The expectation of life of a healthy man of fifty is still reckoned at about twenty years.

[31] 'Hominis ævum cæterorum animalium omnium superat præter admodum paucorum.'—Francis Bacon, *Historia vitæ et mortis*, 1637.

the oncoming of sleep, the approach of the fatal shears will be as generally welcomed as it is now abhorred Such a day is still distant; we can hardly say that its dawning is visible. Let us at least hope that, in the manner depicted by Durer in his well-known etching, the sunshine which science irradiates may eventually put to flight the melancholy which hovers, bat-like, over the termination of our lives, and which even the anticipation of a future happier existence has not hitherto succeeded in dispersing

REPORTS

ON THE

STATE OF SCIENCE.

REPORTS ON THE STATE OF SCIENCE.

The further Tabulation of Bessel and other Functions.—Report of the Committee, consisting of Professor M. J. M. HILL (*Chairman*), Dr J W NICHOLSON (*Secretary*), Professor ALFRED LODGE, Professor L. N G FILON, Sir GEORGE GREENHILL, *and* Mr. J. R. AIREY.

PART I.—*Elliptic Functions.*

THE calculations of the Committee have proceeded steadily during the year, and the results are given in four sheets of tables for four modular angles.

Sir George Greenhill has prepared the following statement for the explanation of the notation, and of the mode of use of the Tables for the various applications which may arise —

The Notation and Use of the Elliptic Function Table.

The Elliptic Integral which arises in a physical problem of Dynamics or Electro-magnetism requires to be carried out to a numerical result, and with as little delay as possible, but so far Table IX in Legendre's '*Fonctions elliptiques*' is the only source available for reducing the labour of the calculation.

This Table IX. of Legendre gives $F(\phi)$, the First Elliptic Integral, and $E(\phi)$ the Second Elliptic Integral, for every degree of ϕ, and for every degree of the modular angle θ, these are defined by

$$(1) \qquad F(\phi) = \int_0^\phi \frac{d\phi}{\Delta\phi}, \qquad E(\phi) = \int_0^\phi \Delta\phi\, d\phi,$$

$$(2) \qquad \Delta\phi = \sqrt{(1 - \kappa^2 \sin^2\phi)}, \qquad \kappa = \sin\theta,\ \kappa' = \cos\theta.$$

Legendre has shown that $F(\phi)$ and $E(\phi)$, together with the complete functions $F(\frac{1}{2}\pi)$ and $E(\frac{1}{2}\pi)$, denoted by K and E, are sufficient for the numerical calculation of the Third Elliptic Integral, when complete, as required, for instance, for Ω, the conical angle subtended by a circular or elliptic disc, which gives the magnetic potential for uniform normal magnetisation, or the apsidal angle of a spinning-top.

But for the general incomplete Elliptic Integral of the Third Kind (E. I. III) the Theta and Eta function of Jacobi is required, and these are given in the Table by the function

$$(3) \qquad A(r), \qquad B(r), \qquad C(r), \qquad D(r),$$

defined by

$$(4) \qquad D(r) = \frac{\Theta(hK)}{\Theta(0K)}, \qquad A(r) = \frac{H(hK)}{H(K)}, \qquad r = 90\,h,$$

$$(5) \qquad C(r) = D(90 - r), \qquad B(r) = A(90 - r).$$

For this purpose it is convenient to follow Abel and take $F(\phi)$ or hK as the argument in the Table, instead of ϕ as in Legendre's Table IX., and to proceed in the tabulation with equal increments of $F(\phi)$, or hK, or $\frac{r}{90}K$; dividing K into 90 degrees, instead of taking equal degree intervals in ϕ, as in Legendre's Table IX.

In this new arrangement r and $hK = \frac{r}{90}K$, or $F(\phi)$, proceeds by equal steps of 1 degree in the quadrant; and then ϕ is tabulated in the column adjacent, and ψ in the column adjacent to $F(\psi)$ or $(1-h)K$ or $\left(1-\frac{r}{90}\right)K$; and in Jacobi's notation ϕ is the amplitude function of hK, and denoted by

$$(6) \qquad \phi = \text{am } hK, \qquad \psi = \text{am}(1-h)K.$$

Further, in Gudermann's abbreviation of Jacobi's notation

$$(7) \qquad \sin\phi = \text{sn } hK, \qquad \cos\phi = \text{cn } hK, \qquad \Delta\phi = \text{dn } hK;$$

and Jacobi shows that, expressed by the function $D(r)$, $A(r)$, $B(r)$, $C(r)$, of the Table

$$(8) \quad \text{sn } hK = \frac{1}{\sqrt{\kappa'}}\frac{A(r)}{D(r)}, \qquad \text{cn } hK = \frac{B(r)}{D(r)}, \qquad \text{dn } hK = \sqrt{\kappa'}\frac{C(r)}{D(r)};$$

implying

$$(9) \qquad A(0) = B(90) = 0, \quad A(90) = B(0) = 1,$$
$$D(0) = C(90) = 1, \quad D(90) = C(0) = \frac{1}{\sqrt{\kappa'}},$$

instead of Jacobi's $\Theta(hK)$ and $H(hK)$.

The function $D(r)$ and $A(r)$, defined in (4), is tabulated, qualified by a denominator, because $D(r)$, $A(r)$. . . can be expressed exactly by surds at the aliquot division values of the quadrant, such as

$$(10) \qquad r = 45;\ 30, 60;\ 18, 36, 54, 72;\ 15, 75, 22\tfrac{1}{2}, \ldots$$

just as the corresponding values in a Circular Function Table, to which the Elliptic Function degenerates when the modular angle $\theta = 0$; and then

$$(11) \qquad A(r) = \sin r^\circ, \qquad B(r) = \cos r^\circ, \qquad D(r) = C(r) = 1.$$

An important check is introduced thereby on the accuracy of the numerical calculation, these check values are mentioned as they arise, and the algebraical formulas were stated in the Report, 1911, the theory being given in 'Phil. Trans.,' A, 1904.

For the Second Elliptic Integral the function $E(r)$ is tabulated, or $F(r) = E(90-r)$; and these are given in terms of Jacobi's Zeta function by

$$(12) \qquad E(r) = \text{zn } hK, \quad F(r) = \text{zn}(1-h)K;$$

and connected with Legendre's function $E(\phi)$ by

$$(13) \qquad \text{zn } hK = E(\phi) - hE = E(\phi) - \frac{E}{K}F(\phi).$$

Jacobi has shown that the Zeta function is connected with the Theta function by the relation

$$(14)\qquad \operatorname{zn} hK = \frac{d\log\Theta(hK)}{dhK}, \text{ or } KE(r) = \frac{d}{90dr}\log D(r).$$

In a physical problem, as of Electro-magnetism or Dynamics, it is the Elliptic Integral which makes an appearance; and the physical student will be anxious to arrive at a numerical result without delay by utilising a Table of the Function.

The integral which arises can be made to depend on three standard forms, called the First, Second, and Third Elliptic Integrals (I., II., and III. E. I.).

These three integrals can be reduced to depend on the differential elements

$$(15)\qquad \frac{ds}{\sqrt{S}},\quad (s-\sigma)\frac{ds}{\sqrt{S}},\quad \frac{1}{s-\sigma}\frac{ds}{\sqrt{S}},$$

where S is a cubic in the variable s, which may be written

$$(16)\qquad S = 4(s-s_1)(s-s_2)(s-s_3)$$

when resolved into factors.

Normalised to a standard form, of zero dimensions, the three integrals are written

$$(\text{I})\int_{s_3}^{s}\frac{\sqrt{(s_1-s_3)}ds}{\sqrt{S}},\qquad (\text{II.})\int\frac{s-\sigma}{\sqrt{(s_1-s_3)}}\frac{ds}{\sqrt{S}},\qquad (\text{III})\int\frac{\frac{1}{2}\sqrt{\Sigma}}{s-\sigma}\frac{ds}{\sqrt{S}},$$

Σ denoting the value of S for $s=\sigma$, and assuming a sequence

$$(17)\qquad \infty > s > s_1 > s_2 > s > s_3 > -\infty.$$

Taking, for example, the interval $s_2 > s > s_3$, the substitution

$$(18)\qquad \begin{aligned} s - s_3 &= (s_2 - s_3)\sin^2\phi,\\ s_2 - s &= (s_2 - s_3)\cos^2\phi,\\ s_1 - s &= (s_1 - s_3)\Delta^2\phi, \end{aligned}$$

$$(19)\qquad \sin^2\theta = \kappa^2 = \frac{s_2-s_3}{s_1-s_3},\qquad \cos^2\theta = \kappa'^2 = \frac{s_1-s_2}{s_1-s_3},$$

reduces (I.) to Legendre's standard form in (1)

$$(20)\qquad \int_{s_3}^{s}\frac{\sqrt{(s_1-s_3)}ds}{\sqrt{S}} = \int_0^{\phi}\frac{d\phi}{\Delta\phi} = F\phi, \text{ or } hK$$

where

$$(21)\qquad \int_{s_3}^{s_2}\frac{\sqrt{(s_1-s_3)}ds}{\sqrt{S}} = \int_0^{\frac{1}{2}\pi}\frac{d\phi}{\Delta} = K.$$

Then (II.) becomes

$$(22)\qquad \int_{s_3}^{s}\frac{(s_1-\sigma)-(s_1-s)}{\sqrt{(s_1-s_3)}}\frac{ds}{\sqrt{S}} = \frac{s_1-\sigma}{s_1-s_3}\int_0^{\phi}\frac{d\phi}{\Delta\phi} - \int_0^{\phi}\Delta\phi d\phi$$

$$= \frac{s_1-\sigma}{s_1-s_3}F(\phi) - E(\phi),$$

and so depends on Legendre's Second Elliptic Integral $E(\phi)$, as well as $F(\phi)$.

Legendre has shown that (III.), taken as a definite integral between the limits s_2 and s_3, can be expressed by $F(\phi)$ and $E(\phi)$, K and E, by means of the equation (p') of his '*Fonctions elliptiques*,' I., p. 141, thus, taking the sequence

(23) $$\infty > \sigma > s_1 > s_2 > s > s_3 > -\infty,$$

so as to avoid an infinity in the integral,

(24) $$\int_{s_1}^{s_2} \frac{\frac{1}{2}\sqrt{\Sigma}}{\sigma - s} \frac{ds}{\sqrt{S}} = \mathrm{K}\ \mathrm{zs}\, f\mathrm{K},$$

and similarly, by an interchange of s and σ,

(25) $$\int_{s_1}^{\infty} \frac{\frac{1}{2}\sqrt{S}}{\sigma - s} \frac{d\sigma}{\sqrt{\Sigma}} = \mathrm{K}\ \mathrm{zn}\ h\mathrm{K} = \mathrm{K}\ \mathrm{E}(\phi) - \mathrm{E}\mathrm{F}(\phi),$$

but now

(26) $$\frac{\sigma - s_3}{s_2 - s_3} = \frac{1}{\kappa^2 \sin^2\chi}, \quad \frac{\sigma - s_2}{s_2 - s_3} = \frac{\Delta^2\chi}{\kappa^2 \sin^2\chi}, \quad \frac{\sigma - s_1}{s_1 - s_3} = \frac{\cos^2\chi}{\sin^2\chi}$$
$$\mathrm{F}(\chi) = f\mathrm{K},$$

but ϕ and hK are given as before in (18), (19), (20).

The function zs fK in (24) is defined by

(27) $$\mathrm{K}\ \mathrm{zs} f\mathrm{K} = \mathrm{K}\ \mathrm{zn} f\mathrm{K} + \mathrm{K}\frac{\mathrm{cn} f\mathrm{K}\ \mathrm{dn} f\mathrm{K}}{\mathrm{sn} f\mathrm{K}}$$
$$= \mathrm{KE}(\chi) - \mathrm{EF}(\chi) + \mathrm{K}\frac{\cos\chi\,\Delta\chi}{\sin\chi},$$
$$= \mathrm{KE}(\chi) - \mathrm{EF}(\chi) + \mathrm{K}\sqrt{\frac{(\sigma - s_1)(\sigma - s_2)}{(\sigma - s_3)(s_1 - s_3)}}.$$

But for a corrected Integral of the III kind, between the limit s_3 and s, the Jacobian Theta function is required, and

(28) $$\int_{s_3}^{s} \frac{\frac{1}{2}\sqrt{\Sigma}}{\sigma - s} \frac{ds}{\sqrt{S}} = f\mathrm{K}\ \mathrm{zs}\ h\mathrm{K} + \tfrac{1}{2}\log\frac{\Theta(f - h)\mathrm{K}}{\Theta(f + h)\mathrm{K}},$$

while

(29) $$\int_{\sigma}^{\infty} \frac{\frac{1}{2}\sqrt{S}}{\sigma - s} \frac{d\sigma}{\sqrt{\Sigma}} = h\mathrm{K}\ \mathrm{zn} f\mathrm{K} + \tfrac{1}{2}\log\frac{\Theta(f - h)\mathrm{K}}{\Theta(f + h)\mathrm{K}},$$
$$= \frac{q}{90}\mathrm{K}\,\mathrm{E}(r) + \tfrac{1}{2}\log\frac{\mathrm{D}(q - r)}{\mathrm{D}(q + r)}$$

in the notation of the Tables, with

(30) $$r = 90h, \qquad q = 0.$$

Or with σ between s_2 and s_3, $s_2 > s$, $\sigma > s_3$, when $\sigma - s$ can vanish, and the integral becomes infinite

$$(31) \qquad \int_{s_1}^{s<\sigma} \frac{\frac{1}{2}\sqrt{\Sigma}}{\sigma - s} \frac{ds}{\sqrt{S}} = -\frac{r}{90} \mathrm{KE}(q) + \tfrac{1}{2}\log\frac{\mathrm{A}(q+r)}{\mathrm{A}(q-r)},$$

$$(32) \qquad \int_{s>\sigma}^{s_2} \frac{\frac{1}{2}\sqrt{\Sigma}}{s - \sigma} \frac{ds}{\sqrt{S}} = \left(1 - \frac{r}{90}\right)\mathrm{KE}(q) + \tfrac{1}{2}\log\frac{\mathrm{B}(r-q)}{\mathrm{B}(r+q)}$$

where

$$(33) \qquad \frac{\sigma - s_3}{s_2 - s_3} = \mathrm{sn}^2 f\mathrm{K}, \quad \frac{s_2 - \sigma}{s_2 - s_3} = \mathrm{cn}^2 f\mathrm{K}, \quad \frac{s_1 - \sigma}{s_1 - s_3} = \mathrm{dn}^2 f\mathrm{K}, \quad q = 90f.$$

Putting $h\mathrm{K} = u$, $f\mathrm{K} = v$, these formulas are obtained by a double integration with respect to u of the relation

$$(34) \quad \mathrm{dn}^2(v+u) - \mathrm{dn}^2(v-u) = \frac{-4\kappa^2 \,\mathrm{sn}\, v \,\mathrm{cn}\, v \,\mathrm{dn}\, v \,\mathrm{sn}\, u \,\mathrm{cn}\, u \,\mathrm{dn}\, u}{(1 - \kappa^2 \mathrm{sn}^2 v \,\mathrm{sn}^2 u)^2};$$

the first integration gives

$$(35) \qquad \mathrm{E\,am}(v+u) + \mathrm{E\,am}(v-u) = \mathrm{C} - \frac{2\dfrac{\mathrm{cn}\, v\,\mathrm{dn}\, v}{\mathrm{sn}\, v}}{1 - \kappa^2 \mathrm{sn}^2 v\,\mathrm{sn}^2 u};$$

$$(36) \qquad \mathrm{E\,am}(v+u) + \mathrm{E\,am}(v-u) - 2\,\mathrm{E\,am}\, v$$

$$= 2\frac{\mathrm{cn}\, v\,\mathrm{dn}\, v}{\mathrm{sn}\, v} - \frac{2\dfrac{\mathrm{cn}\, v\,\mathrm{dn}\, v}{\mathrm{sn}\, v}}{1 - \kappa^2 \mathrm{sn}^2 v\,\mathrm{sn}^2 u};$$

or, in Jacobi's notation,

$$(37) \quad \mathrm{zn}(v+u) + \mathrm{zn}(v-u) - 2\,\mathrm{zn}\, v = \frac{-2\kappa^2 \mathrm{sn}\, v\,\mathrm{cn}\, v\,\mathrm{dn}\, v\,\mathrm{sn}^2 u}{1 - \kappa^2 \mathrm{sn}^2 v\,\mathrm{sn}^2 u}.$$

Defining Jacobi's Theta function by

$$(38) \qquad \frac{d\log\Theta u}{du} = \mathrm{zn}\, u, \qquad \frac{\Theta u}{\Theta 0} = e^{\int \mathrm{zn}\, u\, du}$$

and integrating (37) again with respect to u

$$(39) \qquad \log\Theta(v+u) - \log\Theta(v-u) - 2u\,\mathrm{zn}\, v$$

$$= -\int_0^u \frac{2\kappa^2 \mathrm{sn}\, v\,\mathrm{cn}\, \mathrm{d}n v\,\mathrm{sn}^2 u}{1 - \kappa^2 \mathrm{sn}^2 v\,\mathrm{sn}^2 u}\, du,$$

and this integral is Jacobi's standard form of the Third Elliptic Integral, and denoted by II. (u, v)

Then, with the notation

$$(40) \qquad \mathrm{zs}\, v = \mathrm{zn}\, v + \frac{\mathrm{cn}\, v\,\mathrm{dn}\, v}{\mathrm{sn}\, v} = \frac{d}{dv}\log \mathrm{H}(v)$$

$$(41) \qquad \int_0^u \frac{\dfrac{\mathrm{cn}\, v\,\mathrm{dn}\, v}{\mathrm{sn}\, v}}{1 - \kappa^2 \mathrm{sn}^2 v\,\mathrm{sn}^2 u}\, du = u\,\mathrm{zs}\, v + \tfrac{1}{2}\log\frac{\Theta(v-u)}{\Theta(v+u)},$$

and this integral is converted into the form (III.) by putting

$$(42) \qquad \mathrm{sn}^2 u = \frac{s - s_3}{s_2 - s_3}, \qquad \mathrm{cn}^2 u = \frac{s_2 - s}{s_2 - s_3}, \qquad \mathrm{dn}^2 u = \frac{s_1 - s}{s_1 - s_3},$$

$$(43) \qquad \frac{1}{\kappa^2 \,\mathrm{sn}^2 v} = \frac{\sigma - s_3}{s_2 - s_3}, \qquad \frac{\mathrm{dn}^2 v}{\kappa^2 \,\mathrm{sn}^2 v} = \frac{\sigma - s_2}{s_2 - s_3}, \qquad \frac{\mathrm{cn}^2 v}{\mathrm{sn}^2 v} = \frac{\sigma - s_3}{s_1 - s_3},$$

with the sequence

$$(44) \qquad \infty > \sigma > s_1 > s_2 > s > s_3 > -\infty.$$

So also for the other forms, and thus all these integrals can be made to depend on the numerical value of a function in these Tables, with the addition of an algebraical or logarithmic function in the general case.

But, unfortunately, in the physical problem it is the circular form, so called by Legendre, of the Third Elliptic Integral which is required; here σ lies in the interval $s_1 > \sigma > s_2$, or $s_3 > \sigma > -\infty$; so that Σ is negative, and the standard form must be changed to

$$(45) \qquad \int \frac{\frac{1}{2}\sqrt{(-\Sigma)}}{\sigma - s} \frac{ds}{\sqrt{S}}.$$

The elliptic parameter v is now a fraction of the imaginary period, so that the Theta and D function required would have a complex argument, and the tabular value is not available.

The complete integral is expressible, however, by the function $F(\phi)$ and $E(\phi)$; thus, from Legendre's equation (m') F. E., t. I., p. 138, we find, with

$$s_1 > \sigma > s_2 > s > s_3$$

$$(46) \qquad \int_{s_3}^{s_2} \frac{\frac{1}{2}\sqrt{(-\Sigma)}}{\sigma - s} \frac{ds}{\sqrt{S}} = \tfrac{1}{2}\pi f + \mathrm{K}\,\mathrm{zn}\, f\mathrm{K}' = \mathrm{K}\,\mathrm{E}'(\chi) - (\mathrm{K} - \mathrm{E})\mathrm{F}'(\chi),$$

where

$$(47) \qquad \sin^2\chi = \mathrm{sn}^2 f\mathrm{K}' = \frac{s_1 - \sigma}{s_1 - s_2},$$

$$\cos^2\chi = \mathrm{cn}^2 f\mathrm{K}' = \frac{\sigma - s_3}{s_1 - s_2},$$

$$\Delta^2\chi = \mathrm{dn}^2 f\mathrm{K}' = \frac{\sigma - s_3}{s_1 - s_2};$$

and the accent in $\mathrm{E}'(\chi)$ and $\mathrm{F}'(\chi)$ implies the complementary modulus κ'.

So also for the other forms of the integral; thus

$$(48) \qquad \int_{s_1}^{\infty} \frac{\frac{1}{2}\sqrt{(-\Sigma)}}{s - \sigma} \frac{ds}{\sqrt{S}} = \tfrac{1}{2}\pi(1 - f) - \mathrm{K}\,\mathrm{zn}\, f\mathrm{K}',$$

and four times this integral will give the expression for Ω, the conical angle subtended by a circular or elliptic disc at a point, the equivalent of the magnetic potential for normal magnetisation.

The same complete Elliptic Integral of the Third Kind is required for the determination of the apsidal angle in the Spherical Pendulum or of the symmetrical spinning top.

As another physical application, consider the potential V of a circular disc treated as a plane circle; then, with Maxwell's notation in § 701, 'Electricity and Magnetism,' V may be considered a homogeneous function of a, A, b, of the first degree;

(49) $$V = a\frac{dV}{da} + A\frac{dV}{dA} + b\frac{dV}{db}.$$

Here $\frac{dV}{da}$ is the potential of the rim circumference, and so is given by

(50) $$R = \frac{dV}{da} = \int_0^{2\pi} \frac{a d\theta}{PQ},$$

(51) $$PQ^2 = a^2 + 2Aa\cos\theta + A^2 + b^2 = r_1^2\cos^2\tfrac{1}{2}\theta + r_2^2\sin^2\tfrac{1}{2}\theta,$$

r_1 and r_2 denoting the greatest and least distance of P from the circle; and putting $\theta = 2\omega$,

(52) $$PQ = \surd(r_1^2\cos^2\omega + r_2^2\sin^2\omega) = r_1\surd(1 - c^2\sin^2\omega) = r_1\Delta\omega,$$

$$c^2 = 1 - \frac{r_2^2}{r_1^2},\quad c' = \frac{r_2}{r_1},$$

(53) $$R = \frac{4a}{r_1}\int_0^{\frac{1}{2}\pi}\frac{d\omega}{\Delta\omega} = \frac{4aF}{r_1},\qquad F = F(\tfrac{1}{2}\pi, c)$$

Next $-\frac{dV}{db}$ is the component of attraction norma to the disc, or the magnetic potential for uniform normal magnetisation; and so is given by Ω, the conical angle subtended at P, which depends on the complete Elliptic Integral of the Third Kind.

And Maxwell's M, the coefficient of mutual induction between two parallel circles of radius a and A, a distance b apart, is the Stokes function of Ω,

(54) $$M = -2\pi A\frac{dV}{dA} = \int\frac{-2\pi Aa\cos\theta d\theta}{PQ},$$

(55) $$\frac{dV}{dA} = \int\frac{a\cos\theta d\theta}{PQ} = -Q,$$

where Q is the component attraction of the disc parallel to a diameter, or the magnetic potential when magnetised uniformly in its plane.

Then

(56) $$Q + R = \int_0^{2\pi}\frac{a(1-\cos\theta)d\theta}{PQ} = \int_0^{\frac{1}{2}\pi}\frac{8a\sin^2\omega\, d\omega}{r_1\Delta\omega}$$

$$= \frac{8a}{r_1}\int\frac{1-\Delta^2\omega}{c^2\Delta\omega}d\omega = \frac{8a}{r_1}\frac{F-E}{c^2},\qquad E = E(\tfrac{1}{2}\pi, c).$$

(57) $$Q = \frac{4a}{r_1}\left(2\frac{F-E}{c^2} - F\right).$$

Thus

(58) $$V = aR - AQ - b\Omega,$$

where R, Q, Ω are given by the Elliptic Integral of the First, Second, and Third Kind; and a numerical result is obtained more quickly than by the use of the expansion in Spherical Harmonies.

The expression of Ω in terms of functions of the modulus c or c' is

(59) $$\Omega = 2\pi(1-f) - 2\mathrm{F}\,\mathrm{zn}\,2f\mathrm{F}' - 2\mathrm{E}c'\,\mathrm{sn}\,2f\mathrm{F}',$$

where

(60) $$\mathrm{sn}\,2f\mathrm{F}' = \frac{b}{r_2}, \qquad \mathrm{cn}\,2f\mathrm{F}' = \frac{\mathrm{A}-a}{r_2}, \qquad \mathrm{dn}\,2f\mathrm{F}' = \frac{\mathrm{A}+a}{r_1},$$

and a Quadric Transformation is required, as in Maxwell's § 702, for the expression of Ω in the form given in (48),

(61) $$\Omega = 2\pi(1-f) - 4\mathrm{K}\,\mathrm{zn}\,f\mathrm{K}',$$

and then

(62) $$\mathrm{P} = \frac{8a\mathrm{K}}{r_1+r_2},$$

$$\mathrm{M} = 2\pi\mathrm{QA} = 4\pi(r_1+r_2)(\mathrm{K}-\mathrm{H}) = 8\pi\sqrt{(\mathrm{A}a)}\,\frac{\mathrm{K}-\mathrm{H}}{\sqrt{\kappa}},$$

where

(63) $$\kappa = \frac{1-c'}{1+c'} = \frac{r_1-r_2}{r_1+r_2}, \qquad \sqrt{\kappa} = \frac{2\sqrt{(\mathrm{A}a)}}{r_1+r_2},$$

$$\mathrm{K} = \tfrac{1}{2}(1+c')\,\mathrm{F}, \qquad \mathrm{H} = \mathrm{E}(\tfrac{1}{2}\pi, \kappa)$$

When the disc is dished to a spherical surface of radius c, the potential V assumes a simpler form, given in the 'American Journal of Mathematics,' xxxiii, p. 387, by

(64) $$\mathrm{V} = c\Omega + r'\,\Omega',$$

where Ω' denotes the apparent area at P′, the inverse point of P in the spherical surface, at a distance r' from the centre, and it is not easy to deduce the particular form in (58) by proceeding to $c=\infty$, to obtain a flat disc.

In a more general form, the Elliptic Integral will appear in the standard shape

(65) $$\int\left(1, \text{ or } x-h, \text{ or } \frac{1}{x-k}\right)\frac{dx}{\sqrt{\mathrm{X}}},$$

where X is a quartic function of x, which we suppose resolved into factors

(66) $$\mathrm{X} = (x-\alpha)(x-\beta)(x-\gamma)(x-\delta).$$

The reduction to a preceding form in the variable s is made by a linear transformation depending on the correspondence

(67) $$\left.\begin{array}{c|cccccc} x & \delta, & \alpha, & \beta, & \gamma, & \infty, & k \\ s & \infty, & s_1, & s_2, & s_3, & \sigma, & \tau \end{array}\right|$$

so that

(68) $$\frac{x-\alpha}{x-\delta} = \frac{s-s_1}{\sigma-s_1}, \qquad \frac{x-\beta}{x-\delta} = \frac{s-s_2}{\sigma-s_2}, \qquad \frac{x-\gamma}{x-\delta} = \frac{s-s_3}{\sigma-s_3};$$

(69) $$\frac{x-k}{x-\delta}=\frac{s-\tau}{\sigma-\tau}, \qquad \frac{x-\delta}{\delta-k}=\frac{\sigma-\tau}{s-\sigma}, \qquad \frac{x-k}{\delta-k}=\frac{s-\tau}{s-\sigma};$$

(70) $$\frac{x-\delta}{\alpha-\delta}=\frac{\sigma-s_1}{\sigma-s}, \quad \frac{dx}{x-\delta}=\frac{ds}{\sigma-s}, \quad \frac{\sqrt{\mathrm{X}}}{(x-\delta)^2}=\frac{\sqrt{\mathrm{S}}}{\sqrt{\Sigma}}, \quad \frac{\sqrt{\mathrm{K}}}{(k-\delta)^2}=\frac{\sqrt{\mathrm{T}}}{\sqrt{\Sigma}}$$

if K, T is the value of X, S, for $x = k$, $s = \tau$.

The homogeneity factor

$$\mathrm{M} = \tfrac{1}{2}\sqrt{[(\alpha-\gamma)(\beta-\delta)]}$$

will make

(71) $$\frac{\mathrm{M}dx}{\sqrt{\mathrm{X}}}=\frac{\sqrt{(s_1-s_3)}ds}{\sqrt{\mathrm{S}}},$$

and then

(72) $$\frac{(x-h)dx}{\sqrt{\mathrm{X}}}=\frac{(x-\delta+\delta-h)dx}{\sqrt{\mathrm{X}}},$$

in which

(73) $$\int\frac{(x-\delta)dx}{\sqrt{\mathrm{X}}}=\int\frac{\sqrt{\Sigma}}{\sigma-s}\frac{ds}{\sqrt{\mathrm{S}}},$$

(74) $\displaystyle\int\frac{\sqrt{\mathrm{K}}}{x-k}\frac{dx}{\sqrt{\mathrm{X}}}$ is made to depend on $\displaystyle\int\frac{\sqrt{\mathrm{T}}}{\tau-s}\frac{ds}{\sqrt{\mathrm{S}}}$;

because, conversely

(75) $$\frac{\sqrt{\mathrm{T}}}{\tau-s}\frac{ds}{\sqrt{\mathrm{S}}}=\frac{\delta-k}{x-k}\frac{\sqrt{\mathrm{T}}}{\sqrt{\Sigma}}\frac{\sqrt{\Sigma}}{\sigma-s}\frac{ds}{\sqrt{\mathrm{S}}}$$
$$=\frac{\delta-k}{x-k}\frac{\sqrt{\mathrm{K}}}{(\delta-k)^2}\frac{(x-\delta)dx}{\sqrt{\mathrm{X}}}$$
$$=\left(\frac{1}{\delta-k}-\frac{1}{x-k}\right)\frac{\sqrt{\mathrm{K}}dx}{\sqrt{\mathrm{X}}}.$$

The integrals in (65) can thus be made to depend on a numerical value entered in the Table, of which four specimen pages are given here, calculated for the modular angle

$$\theta = 15°,\ 45°,\ 75°,\ \text{and}\ 80°\cdot 1,\ \text{when}\ \mathrm{K} = 2\mathrm{K}'.$$

It will serve no useful purpose to go much below $\theta=15°$, as the functions are then indistinguishable from

$$\mathrm{D}(r) = 1 + \frac{1-\sqrt{\kappa'}}{2\sqrt{\kappa'}}\,\mathrm{ver}\ 2r°$$

$$\mathrm{C}(r) = 1 + \frac{1-\sqrt{\kappa'}}{2\sqrt{\kappa'}}\,\mathrm{ver}\ 2(90-r)°$$

$$\mathrm{A}(r) = \sin r°, \qquad \mathrm{B}(r) = \cos r°$$

$$\mathrm{E}(r) = \mathrm{F}(r) = \tfrac{1}{2}(1-\kappa')\sin 2r°.$$

ELLIPTIC FUNCTION TABLE. $\theta = 15°$.

K = 1 5981420, K′ = K $\sqrt{3}$ = 2 7680631, E = 1 5441505, E′ = 1 0764051, $\frac{1}{q} = e^{\pi\sqrt{3}}$ = 230 765.

r	F (ϕ)	ϕ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ψ	F (ψ)	90−r
		°							°		
0	0 0000000	0 00	0 0000000	1 00000	0·000000	1 000000	1 01746	0 0000000	90 00	1 5981420	90
1											89
2											88
3	0 0532714	3 05	0 0017963	1 00005	0 052332	0 998629	1 01744	0 0017810	87 05	1 5448706	87
4											86
5											85
6	0 1065428	6 10	0 0035687	1 00019	0 104521	0 994521	1 01729	0 0035388	84 10	1 4915992	84
7											83
8											82
9	0 1598142	9 15	0 0053080	1 00043	0 156423	0 987686	1 01706	0·0052647	81 15	1 4383278	81
10											80
11											79
12	0 2130856	12 20	0 0069848	1 00076	0 207897	0 978144	1 01673	0 0069298	78 20	1 3850564	78
13											77
14											76
15	0 2663570	15 25	0 0085830	1 00117	0 258801	0 965921	1 01631	0 0085189	75 25	1·3317850	75
16											74
17											73
18	0 3196284	18·29	0 0100848	1 00167	0 308996	0 951049	1 01582	0 0100144	72 29	1 2785136	72
19											71
20											70
21	0 3728998	21 33	0 0114789	1 00225	0 358344	0 933571	1 01524	0 0113268	69 33	1 2252422	69

$90-r$	$F(\psi)$	ψ	$F(r)$	$C(r)$	$B(r)$	$A(r)$	$D(r)$	$E(r)$	ϕ	$F(\phi)$	r
22											68
23											67
24	0 4261712	24 37	0 0127347	1 00289	0 406711	0 913534	1 01459	0 0125877	66 37	1 1719708	66
25											65
26											64
27	0 4794426	27 40	0 0138540	1 00360	0 453963	0 890993	1 01388	0 0137133	63 40	1 1186994	63
28											62
29											61
30	0 5327140	30 43	0 0148188	1 00437	0 499972	0 866009	1 01311	0 0146907	60 43	1 0654280	60
31											59
32											58
33	0 5859854	33 45	0 0156197	1 00519	0 544610	0 838652	1 01230	0 0155096	57 45	1 0121566	57
34											56
35											55
36	0 6392568	36 47	0 0162094	1 00604	0 587756	0 808996	1 01144	0 0161229	54 47	0 9588852	54
37											53
38											52
39	0 6925282	39 48	0 0166950	1 00692	0 629292	0 777123	1 01056	0 0166352	51 49	0 9056138	51
40											50
41											49
42	0 7457996	42 49	0 0169596	1 00783	0 669103	0 743120	1 00966	0 0169289	48 50	0 8523424	48
43											47
44											46
45	0 7990710	45 50	0 0170374	1 00874	0 707080	0 707080	1 00874	0 0170374	45 50	0 7990710	45

ELLIPTIC FUNCTION TABLE $\theta = 45°$.

$K = 1{\cdot}8540747 = K'$, $E = 1\ 3506439 = E'$; $\frac{1}{q} = e^{\pi} = 23\ 1407$

r	$F\phi$	ϕ	$E(r)$	$D(r)$	$A(r)$	$B(r)$	$C(r)$	$F(r)$	ψ	$F(\psi)$	$90-r$
		°							°		
0	0 0000000	0 00	0 0000000	1 000000	0 0000000	1 000000	1 18921	0 0000000	90 00	1 8540747	90
1	0 0206008	1 18	0 0055923	1 000059	0 0173224	0 996122	1 18915	0 0047056	89 17	1 8334738	89
2	0 0412017	2 36	0 0111758	1 000241	0 0346396	0 995674	1 18898	0 0094074	88 33	1 8128730	88
3	0 0618025	3 54	0 0167413	1 000518	0 0519469	0 994927	1 18869	0 0141000	87 50	1 7922722	87
4	0 0824033	4 72	0 0222810	1 000920	0 0692389	0 993881	1 18830	0 0187803	86 66	1 7716714	86
5	0 1030041	5 80	0 0277862	1 001437	0 0865108	0 992537	1 18777	0 0234424	85 83	1 7510705	85
6	0 1236050	7 07	0 0332484	1 002067	0 103758	0 990895	1 18714	0 0280824	84 99	1 7304697	84
7	0 1442063	8 25	0 0386583	1 002809	0 120974	0 988956	1 18640	0 0326970	84 15	1 7098689	83
8	0 1648072	9 42	0 0440090	1 003663	0 138156	0 986719	1 18554	0 0372808	83 31	1 6892680	82
9	0 1854075	10 59	0 0492912	1 004629	0 155297	0 984187	1 18457	0 0418289	82 47	1 6686672	81
10	0 2060083	11 76	0 0544860	1 005703	0 172393	0 981358	1 18350	0 0463385	81 62	1 6480664	80
11	0 2266091	12 93	0 0596211	1 006887	0 189438	0 978234	1 18232	0 0508040	80 78	1 6274656	79
12	0 2472100	14 09	0 0646512	1 008177	0 206428	0 974816	1 18103	0 0552214	79 93	1 6068647	78
13	0 2678108	15 25	0 0697440	1 009571	0 223356	0 971105	1 17963	0 0595865	79 08	1 5862639	77
14	0 2884116	16 41	0 0744104	1 011070	0 240224	0 967102	1 17811	0 0636355	78 23	1 5656631	76
15	0 3090124	17 57	0 0791243	1 012671	0 257018	0 962807	1 17653	0 0681424	77 38	1 5450622	75
16	0 3296133	18 72	0 0837189	1 014371	0 273738	0 958223	1 17483	0 0723242	76 53	1 5244614	74
17	0 3502141	19 87	0 0881878	1 016169	0 290378	0 953349	1 17303	0 0764359	75 67	1 5038606	73
18	0 3708149	21 01	0 0925250	1 018062	0 306933	0 948188	1 17118	0 0804741	74 81	1 4832597	72
19	0 3914158	22 15	0 0967253	1 020049	0 323396	0 942741	1 16915	0 0844333	73 94	1 4626589	71
20	0 4120166	23 28	0 100779	1 022127	0 339768	0 937009	1 16707	0 0883098	73 07	1 4420581	70
21	0 4326174	24 41	0 104692	1 024292	0 356039	0 930994	1 16490	0 0920999	72 20	1 4214573	69

90 − r	F (ψ)	ψ	F (r)	C (r)	B (r)	A (r)	D (r)	E (r)	φ	F (φ)	r
22	0 4532183	25 54	0 108449	1 026544	0 372206	0 924697	1 16265	0·0957981	71 33	1 4008564	68
23	0 4738191	26 66	0 112048	1·028879	0 388263	0·918121	1 16031	0 0994005	70 45	1 3802556	67
24	0 4944199	27 78	0 115486	1 031293	0 404206	0 911266	1 15790	0 102666	69 57	1 3596548	66
25	0 5150207	28 89	0 118759	1 033784	0 420030	0 904136	1 15541	0 106302	68 68	1 3390589	65
26	0 5356216	30 00	0 121863	1 036350	0 435731	0 896731	1 15284	0 109592	67 79	1 3184531	64
27	0 5562224	31 10	0 124795	1 038987	0 451303	0 889054	1 15020	0 112771	66 90	1 2978523	63
28	0 5768232	32 20	0 127553	1 041691	0 466743	0 881107	1 14749	0 115833	66 00	1 2772514	62
29	0 5974241	33 29	0 130133	1 044460	0 482044	0 872892	1 14472	0 118774	65 10	1 2566506	61
30	0 6180249	34 37	0 132534	1 047290	0 497204	0 864411	1 14189	0 121592	64 19	1 2360498	60
31	0 6386257	35 45	0 134753	1 050178	0 512217	0 855472	1 13901	0 124281	63·28	1 2154490	59
32	0 6592266	36 52	0 136789	1 053121	0 527078	0 846273	1 13606	0 126838	62 36	1 1948481	58
33	0 6798274	37 59	0 138642	1 056082	0 541783	0 836816	1 13307	0 129259	61 44	1 1742473	57
34	0 7004282	38 66	0 140309	1 059151	0 556327	0 827105	1 13003	0 131541	60 51	1 1536465	56
35	0 7210290	39 71	0 141791	1 062234	0 570707	0 817142	1 12695	0 133678	59 58	1 1330456	55
36	0 7416299	40 76	0 143087	1 065355	0 584917	0 806933	1 12382	0 135669	58 64	1 1124448	54
37	0 7622307	41 80	0 144196	1 068513	0 598953	0 796479	1 12067	0 137510	57 69	1 0918440	53
38	0 7828315	42 84	0 145119	1 071702	0 612811	0 785784	1 11748	0 139197	56 74	1 0712431	52
39	0 8034324	43 87	0 145858	1 074920	0 626487	0 774851	1 11426	0 140727	55 79	1 0506423	51
40	0 8240332	44 90	0 146411	1 078161	0 639975	0 763685	1 11102	0 142097	54 83	1 0300415	50
41	0 8446340	45 92	0 146780	1 081422	0 653273	0 752287	1 10775	0 143304	53 86	1 0094407	49
42	0 8652348	46 93	0 146967	1 08470	0 666375	0 740664	1 10448	0 144345	52 89	0 9888398	48
43	0 8858357	47 94	0 146972	1 08799	0 679279	0 728817	1 10119	0 145217	51 91	0 9682390	47
44	0 9064365	48 94	0 146798	1 09129	0 691978	0 716752	1 09789	0 145583	50 93	0 9476382	46
45	0 9270373	49 94	0 146446	1 09459	0 704471	0 704471	1 09459	0 146446	49 94	0 9270373	45

ELLIPTIC FUNCTION TABLE. $\theta = 75°$.

K = 2·7680631, K′ = 1 598142, E = 1 0764051, E′ = 1·5441505, $\frac{1}{q} = \exp \frac{\pi}{\sqrt{3}} = 6{\cdot}133708$.

r	F (ϕ)	ϕ	E (r)	D (r)	A (r)	B (r)	C (r)	F (r)	ψ	F (ψ)	90−r
		°							°		
0	0 0000000	0 00	0 0000000	1 00000	0 0000000	1 000000	1 96563	0 0000000	90 00	2 7680631	90
1	0 0307563	1 76	0 0187869	1 00029	0 0156467	0 999816	1 96533	0 0098994	89 55	2 7373069	89
2	0 0615125	3 52	0 0375198	1 00116	0 0312921	0 999265	1 96443	0 0197948	89 09	2 7065506	88
3	0 0922688	5 28	0 0561449	1 00260	0 0469637	0 998345	1 96294	0 0296826	88 63	2 6757944	87
4	0·1230250	7 03	0 0746089	1 00462	0 0625723	0 997060	1 96085	0 0395596	88 17	2 6450381	86
5	0 1537813	8 78	0 0928601	1 00721	0 0782041	0 995409	1 95817	0 0494227	87 71	2 6142819	85
6	0 1845375	10 52	0 110848	1 01037	0 0938285	0 993394	1 95490	0 0592690	87 25	2 5835256	84
7	0 2152938	12 25	0 127171	1 01410	0 109444	0 991016	1 95104	0 0677372	86 79	2 5527693	83
8	0 2460501	13 97	0 145843	1 01839	0 125048	0 988278	1 94661	0 0788860	86 32	2 5220131	82
9	0 2768063	15 67	0 162759	1 02323	0 140640	0 985180	1 94160	0 0886517	85 85	2 4912568	81
10	0 3075626	17 37	0 179233	1 02863	0 156217	0 981726	1 93602	0 0983823	85 37	2 4605006	80
11	0 3383188	19 05	0 195225	1 03457	0 171779	0 977918	1 92989	0 108075	84 89	2 4297443	79
12	0 3690751	20 71	0 210701	1 04105	0 187225	0 973760	1 92320	0 117725	84 41	2 3989881	78
13	0 3998313	22 36	0 225628	1 04632	0 202845	0 969253	1 91596	0 127328	83 92	2 3682318	77
14	0 4305876	23 99	0 239978	1 05559	0 218346	0 964403	1 90619	0 136880	83 48	2 3374755	76
15	0 4613439	25 60	0 253725	1 06364	0 233823	0 959212	1 89990	0 146375	82 93	2 3067193	75
16	0 4921001	27 19	0 266847	1 07219	0 249273	0 953684	1 89109	0 155809	82 42	2 2759630	74
17	0 5228564	28 76	0 279326	1 08123	0 264692	0 947823	1 88178	0 165175	81 91	2 2452068	73
18	0 5536126	30 31	0 291146	1 09076	0 280082	0 941634	1 87197	0 174471	81 39	2 2144505	72
19	0 5843689	31 84	0 302294	1 10077	0 295437	0 935121	1 86169	0 183688	80 86	2 1836943	71
20	0 6151251	33 34	0 312762	1 11123	0 310754	0 928288	1 85094	0 192823	80 33	2 1529380	70
21	0 6458814	34 82	0 322543	1 12214	0 326031	0 921141	1 83974	0 201868	79 79	2 1221817	69

90 − r	F(ψ)	ψ	F(r)	C(r)	B(r)	A(r)	D(r)	E′(r)	φ	F(φ)	r
22	0 6766377	36 98	0 331635	1 13349	0 341265	0 913686	1 82810	0 210818	79 24	2 0914255	68
23	0 7073989	37 72	0 340036	1 14526	0 356452	0 905926	1 81604	0 219665	78 68	2 0606692	67
24	0 7381502	39 13	0 347747	1 15744	0 371590	0 897868	1 80357	0 228404	78 11	2 0299130	66
25	0 7689064	40 51	0 354774	1 17001	0 386674	0 889517	1 79071	0 237026	77 53	1 9991567	65
26	0 7996627	41 87	0 361123	1 18297	0 401702	0 880878	1 77747	0 245524	76 93	1 9684005	64
27	0 8304189	43 20	0 366801	1 19628	0 416668	0 871958	1 76387	0 253891	76 33	1 9376442	63
28	0 8611752	44 51	0 371818	1 20995	0 431570	0 862763	1 74993	0 262119	75 72	1 9068879	62
29	0 8919315	45 80	0 376187	1·22395	0 446403	0 853299	1 73566	0 270196	75·09	1 8761317	61
30	0 9226877	47 06	0 379918	1 23827	0 461163	0 843571	1 72108	0 278119	74 45	1 8453754	60
31	0 9534440	48 29	0 383027	1 25288	0 475846	0 833587	1 70622	0 285874	73 80	1 8146192	59
32	0 9842002	49 50	0 385529	1 26778	0 490446	0 823352	1 69109	0 293452	73 14	1 7838629	58
33	1 0149565	50 68	0 387440	1 28295	0 504960	0 812873	1 67570	0 300843	72 46	1 7531067	57
34	1 0457127	51 84	0 388734	1 29835	0 519382	0 802157	1 66008	0 308036	71 77	1 7223504	56
35	1 0764690	52 98	0 389552	1 31399	0 533708	0·791209	1 64425	0 315021	71 06	1 6915941	55
36	1 1072253	54 09	0 389791	1 32983	0 547982	0 780037	1 62828	0 321785	70 33	1 6608379	54
37	1 1379815	55 17	0 389505	1 34587	0 562049	0 768646	1 61208	0 328339	69 59	1 6300816	53
38	1 1687378	56 23	0 388717	1 36207	0 576054	0 757045	1 59568	0 334603	68 84	1 5993254	52
39	1 1994940	57 27	0 387442	1 37843	0 589941	0 745239	1 57919	0 340682	68 06	1 5685691	51
40	1 2302503	58 29	0 385699	1 39492	0 603704	0 733234	1 56260	0 346289	67 27	1 5378129	50
41	1 2610065	59 28	0 383506	1 41152	0 617339	0 721037	1 54591	0 351860	66 46	1 5070566	49
42	1 2917628	60 25	0 380881	1 42821	0 630838	0 708656	1 52914	0 357031	65 63	1 4763003	48
43	1 3225191	61 20	0 377841	1 44497	0 644196	0 696096	1 51233	0 361887	64 79	1 4455806	47
44	1 3532753	62 13	0 374406	1 46179	0 657407	0 683363	1 49549	0 366411	63 93	1 4147878	46
45	1 3840316	63 04	0 370590	1 47863	0 670465	0 670465	1 47863	0 370590	63 04	1 3840316	45

ELLIPTIC FUNCTION TABLE $\theta = 80° 1$

$K = 3\ 163232 = 2K'$, $E = 1\ 0394658$, $E' = 1\ 559123$, $\frac{1}{q} = e^{\frac{1}{2}\pi} = 4\ 81048$

r	$F\phi$	ϕ	$E(r)$	$D(r)$	$A(r)$	$B(r)$	$C(r)$	$F(r)$	ψ	$F\psi$	$90-r$
		°							°		
0	0 0000000	00 00	0 0000000	1 00000	0 0000000	1 000000	2 41422	0 0000000	90 00	3 1632320	90
1	0 0351470	05 33	0 0236055	1 00042	0·0145672	0 996072	2 41377	0 0105122	89 66	3 1280850	89
2	0·0702940	06 37	0 0471266	1 00168	0 0291353	0 995482	2 41248	0 0210228	89·32	3 0929380	88
3	0 1054411	07 78	0 0704807	1 00373	0 0437045	0 994492	2 41020	0 0315278	88 98	3 0577909	87
4	0 1405881	09 40	0·0935852	1 00663	0 0582762	0 993121	2 40709	0 0420255	88 63	3 0226439	86
5	0·1757351	11 15	0 116354	1·01036	0 0728510	0·991335	2 40309	0 0525198	88 28	2·9874969	85
6	0 2108821	12 94	0 138730	1 01490	0 0874299	0 989170	2 39821	0 0629870	87 92	2 9523499	84
7	0·2460292	14 78	0 160624	1 02026	0 102012	0 986619	2 39246	0 0734471	87 56	2 9172028	83
8	0·2811762	16 61	0·181970	1·02643	0 116600	0 983674	2·38585	0 0838875	87 20	2 8820558	82
9	0 3163232	18 44	0 2027083	1 03340	0 131193	0 980347	2 37839	0 0943086	86 84	2 8469088	81
10	0 3514702	20 27	0·222777	1·04116	0 145791	0 976646	2 37008	0 104707	86 47	2 8117618	80
11	0 3866172	22 09	0 242131	1·04971	0 160394	0 972566	2·36094	0·115075	86 10	2 7766148	79
12	0 4217643	23 90	0 2607148	1 05903	0 175004	0 968111	2 35098	0 125414	85 72	2 7414677	78
13	0 4569113	25 69	0 278492	1 06912	0 189616	0·963282	2 34021	0·135721	85 34	2 7063207	77
14	0·4920583	27 47	0 295428	1·07997	0 204239	0·958075	2 32864	0·145990	84 96	2 6711737	76
15	0 5272053	29 23	0 311493	1 09156	0 218864	0 952541	2 31631	0 156220	84 57	2 6360267	75
16	0 5623524	30 96	0·326664	1 10388	0 233498	0 946636	2 30320	0 166406	84 17	2 6008796	74
17	0 5974994	32 66	0 340925	1 11692	0 248125	0 940378	2 28935	0 176543	83 77	2 5657326	73
18	0 6326464	34 33	0 354265	1 13066	0 262760	0 933773	2 27438	0 186628	83 36	2 5305856	72
19	0 6677934	35 97	0·366675	1 14509	0 277394	0 926839	2 25950	0 196653	82 95	2 4954386	71
20	0 7029404	37 58	0·378154	1 16019	0 292031	0 919564	2 24353	0 206623	82 53	2 4602916	70
21	0 7380875	39 15	0 388707	1 17594	0 306664	0 911962	2 22689	0 216524	82 10	2 4251445	69

90−r	Fψ	ψ	E(r)	C(r)	B(r)	A(r)	D(r)	F(r)	ψ	Fψ	r
22	0 7732345	40 69	0 396459	1 19233	0 321294	0 904045	2·20962	0 224474	81 65	2 3899975	68
23	0 8083815	42 19	0 406863	1 20934	0·335917	0 895809	2 19172	0 236302	81 19	2 3548505	67
24	0 8435285	43 68	0 414883	1 22695	0 350531	0 887274	2 17322	0 245773	80 72	2 3197035	66
25	0 8786756	45 14	0 421828	1 24513	0 365133	0 878439	2 15416	0 255351	80 24	2 2845564	65
26	0 9138226	46 56	0 427914	1 26388	0 379723	0 869306	2 13455	0 264835	79 75	2 2494094	64
27	0 9489696	47 94	0 433163	1 28317	0 394294	0 859692	2 11442	0 274217	79 25	2 2142624	63
28	0 9841166	49 28	0 437594	1 30297	0 408845	0 850196	2 09378	0 283484	78 74	2 1791154	62
29	1 0192636	50 59	0 441236	1 32326	0 423870	0 840236	2 07268	0 292637	78 21	2 1439684	61
30	1 0544107	51 87	0 444114	1·34403	0 437868	0 830015	2 05113	0 301661	77 67	2 1088213	60
31	1 0895577	53 12	0 446087	1 36524	0 452333	0 819360	2 02915	0 310381	77 12	2 0736743	59
32	1 1247047	54 34	0 447353	1 38687	0 466761	0 808450	2 00682	0 318958	76 55	2 0385273	58
33	1 1598517	55 53	0 447805	1 40884	0 481132	0 797312	1 98395	0 327524	75 97	2 0033803	57
34	1 1949988	56 69	0 447888	1 43130	0 495484	0 785945	1 96107	0 335654	75 37	1 9682332	56
35	1 2301458	57 82	0 447214	1 45405	0 509771	0 774362	1 93772	0 343753	74 75	1 9330862	55
36	1 2652928	58 92	0 445955	1 47711	0 523999	0 762563	1 91412	0 351674	74 11	1 8979392	54
37	1 3004398	59 99	0 444133	1 50047	0 538163	0 750574	1 89028	0 359399	73 46	1 8627922	53
38	1 3355868	61 03	0 441637	1 52408	0 552258	0 738388	1 86619	0 367083	72 79	1 8276452	52
39	1 3707339	62 04	0 438925	1 54794	0 566278	0 726016	1 84197	0 374230	72 10	1 7924981	51
40	1 4058809	63 02	0 435596	1 57200	0 580214	0 713473	1 81756	0 381307	71 39	1 7573511	50
41	1 4410279	63 97	0 431815	1 59624	0 594062	0 700756	1 79304	0 388138	70 66	1 7222041	49
42	1 4761749	64 89	0 427607	1 62063	0 607813	0 687893	1 76846	0 394706	69 91	1 6870571	48
43	1 5113220	65 79	0 422994	1 64514	0 621462	0 674873	1 74379	0 400992	69 14	1 6519100	47
44	1 5464690	66 67	0 418011	1 66975	0 635000	0 661712	1 71911	0 406990	68 35	1 6167630	46
45	1 5816160	67 50	0 414213	1 69441	0 648419	0 648419	1 69441	0 414213	67 50	1 5816160	45

PART II.—*Bessel Functions*

During the course of the year Professor A G. Webster has kindly placed at the disposal of the Committee some tables of Lord Kelvin's functions ber x, bei x, and their derivates which he has calculated. The importance and value of these Tables, which will be of especial service to electrical engineering, are such that the Committee feel justified in undertaking their publication in their report They are also desirous that Professor Webster should be elected to the Committee. The Tables are given on pp. 57-68

A short table of the Bessel functions was printed by the Association in 1896

The grant of 15*l*. has been expended in connexion with the Tables of Elliptic Functions—the special purpose for which it was given by the Association. The Committee desires to apply this year for an increased grant of 30*l*, which would greatly facilitate the work.

The Committee does not feel justified in asking the Association to print further Tables this year, and is accordingly reserving a report on the remainder of the work until next year.

TABLE OF THE FUNCTION ber x

x	ber x	Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	Δ_6	Δ_7
0 1	+0 999998438	—	—	—	—	—	—	—
0 2	0 999975000	−23438	—	—	—	—	—	—
0 3	0 999873438	101562	−78124	—	—	—	—	—
0 4	0 999600004	273434	171872	−93748	—	—	—	—
0·5	0 999023464	576540	303106	131234	−37486	—	—	—
0 6	0 997975114	1048350	471810	168704	37470	+16	—	—
0·7	0 996248828	1726286	677936	206126	37422	48	+32	—
0 8	0 993601138	2647690	921404	243468	37342	80	32	0
0·9	0 989751357	3849781	1202091	280687	37219	123	43	+11
1 0	0 984381781	5369576	1519795	317704	37017	202	79	36
1 1	0 977137973	7243808	1874232	354437	36733	284	82	3
1·2	0 967629156	9508817	2265009	390777	36340	393	109	27
1 3	0 955428747	12200409	2691592	426583	35806	534	141	32
1 4	0 940075057	15353690	3153281	461689	35106	700	166	25
1 5	0 921072184	19002873	3649183	495902	34213	893	193	27
1 6	0 897891139	23181045	4178172	528989	33087	1126	233	40
1 7	0 869971237	27919902	4738857	560685	31696	1391	265	32
1 8	0 836721794	33249443	5329541	590684	29999	1697	306	41
1 9	0 797524167	39197627	5948184	618643	27959	2040	343	37
2 0	0 751734183	45789984	6592357	644173	25530	2429	389	46
2 1	0 698685001	53049182	7259198	666841	22668	2862	433	44
2 2	0 637690457	60994544	7945362	686164	19323	3345	483	50
2 3	0 568048926	69641531	8646987	701625	15461	3862	517	34
2 4	0 489047772	79001154	9359623	712636	11011	4450	588	71
2 5	0 399968417	89079355	10078201	718578	5942	5069	619	31
2 6	0 300092090	99876327	10796972	718771	−193	5749	680	61
2 7	0 188706304	111385786	11509459	712487	+6284	6477	728	48
2 8	+0 065112108	123594196	12208410	698951	13536	7252	775	47
2 9	−0 071367826	136479934	12885738	677328	21623	8087	835	60
3 0	0 221380249	150012423	13532489	646751	30577	8954	867	32
3 1	0 385531455	164151206	14138783	606294	40457	9880	926	59
3 2	0 564376430	178844975	14693769	554986	51308	10851	971	45

TABLE OF THE FUNCTION ber x—*continued*

x	ber x	Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	Δ_6	Δ_7
3 3	0 758407012	194030582	15185607	491838	63148	11840	989	18
3·4	0 968038995	209631983	15601401	415794	76044	12896	1056	+67
3 5	1 193598180	225559185	15927202	325801	89993	13949	1053	− 3
3 6	1 435305322	241707142	16147957	220755	105046	15053	1104	+51
3 7	1 693259984	257954662	16247520	−99563	121192	16146	1093	−11
3 8	1 967423273	274163289	16208627	+38893	138456	17264	1118	+25
3 9	−2 257599466	−290176193	−16012904	+195723	+156830	+18374	+1110	−8
4 0	2 563416557	305817091	15640898	372006	176283	19453	1079	−31
4 1	2 884305732	320889175	15072084	568814	196808	20525	1072	7
4 2	3 219479832	335174100	14284925	787159	218345	21537	1012	60
4 3	3 567910863	348431031	13256931	1027994	240835	22490	953	59
4 4	3 928306621	360395758	11964727	1292204	264210	23375	885	68
4 5	4 299086552	370779931	10384173	1580554	288350	24140	765	120
4 6	4 678356937	379270385	8490454	1893719	313165	24815	675	90
4 7	5 063885587	385528650	6258265	2232189	338470	25305	490	185
4 8	5 453076175	389190588	3661938	2596327	364138	25668	363	127
4 9	5 842942442	389866267	−675679	2986259	389932	25794	+126	237
5 0	6 230082479	387140037	+2726230	3401909	415650	25722	−72	198
5 1	6 610653357	380570878	6569159	3842929	441020	25370	352	280
5 2	6 980346403	369693046	10877832	4308673	465744	24724	646	294
5 3	7 334363435	354017032	15676014	4798182	489509	23765	959	313
5 4	7 667394351	333030916	20986116	5310102	511920	22411	1354	395
5 5	7 973596451	306202100	26828816	5842700	532598	20678	1733	379
5 6	8 246575962	272979511	33222589	6393773	551073	18475	2203	470
5 7	8 479372252	232796290	40183221	6960632	566859	15786	2689	486
5 8	8 664445263	185073011	47723279	7540058	579426	12567	3219	530
5 9	8 793666753	129221490	55851521	8128242	588184	8758	3809	590
6 0	8 858315966	−64649213	64572277	8720756	592514	+4330	4428	619
6 1	8 849080413	+9235553	73884766	9312489	591733	−781	5111	683
6 2	8 756062474	93017939	83782386	9897620	585131	6602	5821	710
6 3	8 568792593	187269881	94251942	10469556	571936	13195	6593	772
6 4	8 276249873	292542720	105272839	11020897	551341	20595	7400	807

6 5	7 866890928	409358945	116816225	11543386	522489	28852	8257	857
6 6	7 328687885	538203043	128844098	12027873	484487	38002	9150]	893
6 7	6 649176464	679511421	141308378	12464280	436407	48080	10078	928
6 8	5 815515115	833661349	154149928	12841550	377270	59137	11057	979
6 9	4 814556200	1000958915	167297566	13147638	306088	71182	12045	988
7 0	3 632930243	1181625957	180667042	13369476	221838	84250	13068	1023
7 1	2 257144280	1375785963	194160006	13492964	123488	98350	14100	1032
7 2	−0 673695379	1583448901	207662938	13502932	+9968	113520	15170	1070
7 3	+1 130799653	1804495032	221046131	13383193	−119739	129707	16187	1017
7 4	3 169457312	2038657659	234162627	13116496	266697	146958	17251	1064
7 5	5 454962184	2285504872	246847213	12684586	431910	165213	18255	1004
7 6	7 999382494	2544420310	258915438	12068225	616361	184451	19238	983
7 7	+10 813965476	+2814582982	+270162672	+11247234	−820991	−204630	−20179	−941
7 8	13 908911711	3094946235	280363253	10200581	1046653	225662	21032	853
7 9	17 293127645	3384215934	289269699	8906446	1294135	247482	21820	788
8 0	20 973955611	3680827966	296612032	7342333	1564113	269978	22496	676
8 1	24 956880800	3982925189	302097223	5485191	1857142	293029	23051	555
8 2	29 245214796	4288333996	305408807	3311584	2173607	316465	23436	385
8 3	33 839755432	4594540636	306206640	+797833	2513751	340144	23679	−243
8 4	38 738422961	4898667529	304126893	−2079747	2877580	363829	23685	−6
8 5	43 935872751	5197449790	298782261	5344632	3264885	387305	23476	+209
8 6	49 423084977	5487212226	289762436	9019825	3675193	410308	23003	+473
8 7	55 186932099	5763847122	276634896	13127540	4107725	432532	22224	779
8 8	61 209725224	6022793125	258946003	17688893	4561353	453628	21096	1128
8 9	67 468740848	6259015624	236222499	22723504	5034611	473258	19630	1466
9 0	73 935729857	6466989009	207973385	28249114	5525610	490999	17741	1889
9 1	80 576411145	6640681288	173692279	34281106	6031992	506382	15383	2358
9 2	87 349952674	6773541529	132860241	40832038	6550932	518940	12558	2825
9 3	94 208443358	6858490684	84949155	47911086	7079048	528116	9176	3382
9 4	101 096359718	6887916360	+29425676	55523479	7612393	533345	5229	3947
9 5	107 950031881	6853672163	−34244197	63669873	8146394	534001	−656	4573
9 6	114 697114173	6747082292	106589871	72345674	8675801	529407	+4594	5250
9 7	121 256066255	6558952082	188130210	81540339	9194665	518864	10543	5949
9 8	127 535651521	6279585266	279366816	91236606	9696267	501602	17262	6719
9 9	133 434460262	5898808741	380776525	101409709	10173103	476836	24766	7504
10 0	138 840465942	5406005680	492803061	112026536	10616827	443724	33112	8346

TABLE OF THE FUNCTION bei x.

x	bei x	Δ_1	Δ_2	Δ_3	Δ_4	∇_5	Δ_6	Δ_7
0 1	+0 002500000	—	—	—	—	—	—	—
0 2	0 009999972	+7499972	—	—	—	—	—	—
0 3	0 022499684	12499712	+4999740	—	—	—	—	—
0 4	0 039998222	17498538	4998826	−914	—	—	—	—
0 5	0 062493218	22494996	4996458	2368	−1454	—	—	—
0 6	0 089979750	27486532	4991536	4922	2554	−1100	—	—
0 7	0 122448939	32469189	4982657	8879	3957	1403	−303	—
0 8	0 159886230	37437291	4968102	14555	5676	1719	316	−13
0 9	0 202269363	42383133	4945842	22260	7705	2029	310	+6
1 0	0 249566040	47296677	4913544	32298	10038	2333	304	+6
1 1	0 301731269	52165229	4868552	44992	12694	2656	323	−19
1 2	0 358704420	56973151	4807922	60630	15638	2944	288	35
1 3	0 420405966	61701546	4728395	79527	18897	3259	315	27
1 4	0 486733934	66327968	4626422	101973	22446	3549	290	+25
1 5	0 557560062	70826128	4498160	128262	26289	3843	294	−4
1 6	0 632725677	75165615	4339487	158673	30411	4122	279	+15
1 7	0 712037292	79311615	4146000	193487	34814	4403	281	−2
1 8	0 795261955	83224663	3913048	232952	39465	4651	248	+33
1 9	0 882122341	86860386	3635723	277325	44373	4908	247	1
2 0	0 972291627	90169286	3308900	326823	49498	5125	217	30
2 1	1 065388161	93096534	2927248	381652	54829	5331	206	11
2 2	1 160969944	95581783	2485249	441999	60347	5518	187	19
2 3	1 258528975	97559031	1977248	508001	66002	5655	137	50
2 4	1 357485476	98956501	1397470	579778	71777	5775	120	17
2 5	1 457182044	99696568	+740067	657403	77625	5848	73	47
2 6	1 556877774	99695730	−838	740905	83502	5877	−29	44
2 7	1 655742407	98864633	831097	830259	89354	5852	+25	54
2 8	1 752850564	97108157	1756476	925379	95120	5766	86	61
2 9	1 847176116	94325552	2782605	1026129	100750	5630	136	50
3 0	1 937586785	90410669	3914883	1132278	106149	5399	231	95
3 1	2 022839042	85252257	5158412	1243529	111251	5102	297	66
3 2	2 101573388	78734346	6517911	1359499	115970	4719	383	86

3 3	2 172310131	70736743	7997603	1479692	120193	4223	496	113
3 4	+2 233445750	+61135619	−9601124	−1603521	−123829	−3636	+587	+91
3 5	2 283249967	49804217	11331402	1730278	126757	2928	708	121
3 6	2 319863655	36613688	13190529	1859127	128849	2092	836	128
3 7	2 341297714	21434059	15179629	1989100	129973	1124	968	132
3 8	2 345433061	+4135347	17298712	2119083	129983	−10	1114	146
3·9	2 330021882	−15411179	19546526	2247814	128731	+1252	1262	148
4 0	2 292690323	37331559	21920380	2373854	126040	2691	1439	177
4 1	2 230942780	61747543	24415984	2495604	121750	4290	1599	160
4 2	2 142167987	88774793	27027250	2611266	115662	6088	1798	199
4 3	2 023647069	118520918	29746125	2718875	107609	8053	1965	167
4 4	1 872563796	151083273	32562355	2816230	97355	10254	2201	236
4 5	1 686017204	186546592	35463319	2900964	84734	12621	2367	166
4 6	1 461036836	224980368	38433776	2970457	69493	15241	2620	253
4 7	1 194600797	266436039	41455671	3021895	51438	18055	2814	194
4 8	0 883656854	310943943	44507904	3052233	30338	21100	3045	231
4 9	0 525146811	358510043	47566100	3058196	−5963	24375	3275	230
5 0	+0 116034382	409112429	50602386	3036286	+21910	27873	3498	223
5 1	−0 346663218	462697600	53585171	2982785	53501	31591	3718	220
5 2	0 865839727	519176509	56478909	2893738	89047	35546	3955	237
5 3	1 444260151	578420424	59243915	2765006	128732	39685	4139	184
5 4	2 084516693	640256542	61836118	2592203	172803	44071	4386	247
5 5	2 788980155	704463462	64206920	2370802	221401	48598	4527	141
5 6	3 559746593	770766438	66302976	2096056	274746	53345	4747	220
5 7	4 398579111	838832518	68066080	1763104	332952	58206	4861	114
5 8	5 306844640	908265529	69433011	1366931	396173	63221	5015	154
5 9	6 285445623	978600983	70335454	902443	464488	68315	5094	79
6 0	7 334746541	1049300918	70699935	−364481	537962	73474	5159	65
6 1	8 454495269	1119748728	70447810	+252125	616606	78644	5170	+11
6 2	9 643739286	1189244017	69495289	952521	700396	83790	5146	−24
6 3	10·900736825	1256997539	67753522	1741767	789246	88850	5060	86
6 4	12 222863128	1322126303	65128764	2624758	882991	93745	4895	165
6 5	13 606512001	1383648873	61522570	3606194	981436	98445	4700	195

TABLE OF THE FUNCTION bei x—*continued*

x	bei x	Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	Δ_6	Δ_7	Δ_8
6 6	−15 046992991	−1440480990	−56832117	+4690453	+1084259	+102823	+4378	−322	−127
6 7	16 538424538	1491431547	50950557	5881560	1191107	106848	4025	353	31
6 8	18 073623609	1535199071	43767524	7183033	1301473	110366	3518	507	154
6 9	19 643992365	1570368756	35169685	8597839	1414806	113333	2967	551	44
7 0	21 239402580	1595410215	25041459	10128226	1530387	115581	2248	719	168
7 1	22 848078597	1608676017	−13265802	11775657	1647431	117044	1463	785	66
7 2	24 456479797	1608401200	+274817	13540619	1764962	117531	+487	976	191
7 3	26 049183639	1592703842	15697358	15422541	1881922	116960	−571	1058	82
7 4	27 608770523	1559586884	33116958	17419600	1997059	115137	1823	1252	194
7 5	29 115711867	1506941344	52645540	19528582	2108982	111923	3214	1391	139
7 6	30 548262965	1432551098	74390246	21744706	2216124	107142	4781	1567	176
7 7	31 882362359	1334099394	98451704	24061458	2316752	100628	6514	1733	166
7 8	33 091539670	1209177311	124922083	26470379	2408921	92169	8459	1945	212
7 9	34 146833988	1055294318	153882993	28960910	2490531	81610	10559	2100	155
8 0	35 016725165	869891177	185403141	31520148	2559238	68707	12903	2344	244
8 1	35 667080514	650355349	219535828	34132687	2612539	53301	15406	2503	159
8 2	36 061119681	394039167	256316182	36780354	2647667	35128	18173	2767	264
8 3	36 159400616	−98280935	295758232	39442050	2661696	+14029	21099	2926	159
8 4	35 919829830	+239570786	337851721	42093489	2651439	−10257	24286	3187	261
8 5	35 297700300	622129530	382558744	44707023	2613534	37905	27648	3362	175
8 6	34 245760640	1051939660	429810130	47251386	2544363	69171	31266	3618	256
8 7	32 714319308	1531441332	479501672	49691542	2440156	104207	35036	3770	152
8 8	30 651387879	2062931429	531490097	51988425	2296883	143273	39066	4030	260
8 9	8 002867538	2648520341	585588912	54098815	2110390	186493	43220	4154	124
9 0	24 712783168	3290084370	641564029	55975117	1876302	234088	47595	4375	221
9 1	20 723569533	3989213635	699129265	57565236	1590119	286183	52095	4500	125
9 2	15 976414197	4747155336	757941701	58812436	1247200	342919	56736	4641	141
9 3	10 411661917	5564752280	817596944	59655243	842807	404393	61474	4738	97
9 4	−3 969285324	6442376593	877624313	60027369	+372126	470681	66288	4814	76
9 5	+3 410573282	7379858606	937482013	59857700	−169669	541795	71114	4826	12
9 6	11 786984189	8376410907	996552301	59070288	787412	617743	75948	4834	−8
9 7	21 217531810	9430547621	1054136714	57584413	1485875	698463	80720	4772	+62
9 8	31 757530896	10539999086	1109451465	55314751	2269662	783787	85324	4604	168
9 9	43 459152933	11701622037	1161622951	52171486	3143265	873603	89816	4492	112
10 0	56 370458554	12911305621	1209683584	48060633	4110853	967588	93985	4169	323

TABLE OF THE DERIVED FUNCTION ber′ x

x	ber′ x	Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	Δ_6	Δ_7
0 1	−0 000062500	—	—	—	—	—	—	—
0 2	0 000499999	−437499	—	—	—	—	—	—
0 3	0 001687488	1187489	−749990	—	—	—	—	—
0 4	0 003999911	2312423	1124934	−374944	—	—	—	—
0 5	0 007812076	3812165	1499742	374808	+136	—	—	—
0 6	0 013498481	5686405	1874240	374498	310	+174	—	—
0 7	0 021433032	7934551	2248146	373906	592	282	+108	—
0 8	0 031988623	10555591	2621040	372894	1012	420	138	+30
0 9	0 045536553	13547930	2992339	371299	1595	583	163	25
1 0	0 062445752	16909199	3361269	368930	2369	774	191	28
1 1	0 083081791	20636039	3726840	365571	3359	990	216	25
1 2	0 107805642	24723851	4087812	360972	4599	1240	250	34
1 3	0 136972169	29166527	4442676	354864	6108	1509	269	19
1 4	0 170928324	33956155	4789628	346952	7912	1804	295	26
1 5	0 210011017	39082693	5126538	336910	10042	2130	326	31
1 6	0 254544638	44533621	5450928	324390	12520	2478	348	22
1 7	0 304838207	50293569	5759948	309020	15370	2850	372	24
1 8	0 361182125	56343918	6050349	290401	18619	3249	399	27
1 9	0 423844516	62662391	6318473	268124	22277	3658	409	10
2 0	0 493067125	69222609	6560218	241745	26379	4102	444	35
2 1	0 569060755	75993630	6771021	210803	30942	4563	461	+17
2 2	0 652000244	82939489	6945859	174838	35965	5023	460	—
2 3	0 742018947	90018703	7079214	133355	41483	5518	495	+35
2 4	0 839202721	97183774	7165071	85857	47498	6015	497	2
2 5	0 943583409	104380688	7196914	−31843	54014	6516	501	4
2 6	1 055131815	111548406	7167718	+29196	61039	7025	509	+8
2 7	1 173750173	118618358	7069952	97766	68570	7531	506	−3
2 8	1 299264112	125513939	6895581	174371	76605	8035	504	−2
2 9	1 431414136	132150024	6636085	259496	85125	8520	485	−19
3 0	1 569846632	138432496	6282472	353613	94117	8992	472	13
3 1	1 714104430	144257798	5825302	457170	103557	9440	448	24
3 2	1 863616954	149512524	5254726	570576	113406	9849	409	39

TABLE OF THE DERIVED FUNCTION ber′ x—*continued*

x	ber′ x	Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	Δ_6	Δ_7
3 3	2 017689996	154073042	4560518	694208	123632	10226	377	32
3 4	2 175495175	157805179	3732137	828381	134173	10541	315	62
3 5	−2 336059130	−160563955	2758776	+973361	+144980	+10807	+266	−49
3 6	2 498252527	162193397	1629442	1129334	155973	10993	186	80
3 7	2 660778962	162526435	−333038	1296404	167070	11097	104	82
3 8	2 822163850	161384888	+1141547	1474585	178181	11111	+14	90
3 9	2 980743427	158579577	2805311	1663764	189179	10998	−113	127
4 0	3 134653964	153910537	4669040	1863729	199965	10786	212	99
4 1	3 281821353	147167389	6743148	2074108	210379	10414	372	160
4 2	3 419951224	138129871	9037518	2294370	220262	9883	531	159
4 3	3 546519744	126568520	11561351	2523833	229463	9201	682	151
4 4	3 658765306	112245562	14322958	2761607	237774	8311	890	208
4 5	3 753681326	94916020	17329542	3006584	244977	7203	1108	218
4 6	3 828010348	74329022	20586998	3257456	250872	5895	1308	200
4 7	3 878239739	50229391	24099631	3512633	255177	4305	1590	282
4 8	3 900599216	−22359477	27869914	3770283	257650	2473	1832	242
4 9	3 891060511	+ 9538705	31898182	4028268	257985	+335	2138	306
5 0	3 845339473	45721038	36182333	4284151	255883	−2102	2437	299
5 1	3 758900943	86438530	40717492	4535159	251008	4875	2773	336
5 2	3 626966748	131934195	45495665	4778173	243014	7994	3119	346
5 3	3 444527187	182439561	50505366	5009701	231528	11486	3492	373
5 4	3 206356389	238170798	55731237	5225871	216170	15358	3872	380
5 5	2 907031958	299324431	61153633	5422396	196525	19645	4287	415
5 6	2 540959318	366072640	66748209	5594576	172180	24345	4700	413
5 7	2 102401197	438558121	72485481	5737272	142696	29484	5139	439
5 8	1 585512696	516888501	78330380	5844899	107627	35069	5585	446
5 9	0 984382394	601130302	84241801	5911421	66522	41105	6036	451
6 0	−0 293079967	691302427	90172125	5930324	+18903	47619	6514	478
6 1	+0 494289242	787369209	96066782	5894657	−35667	54570	6951	437
6 2	1 383522213	889232971	101863762	5796980	97677	62010	7440	489
6 3	2 380248360	996726147	107493176	5629414	167566	69889	7879	439
6 4	3 489851325	1109602965	112876818	5383642	245772	78206	8317	438

65	4 717382012	1227530687	117927722	5050904	332738	86966	8760	443
66	6 067462487	1350080475	122549788	4622066	428838	96100	9134	374
67	7 544180362	1476717875	126637400	4087612	534454	105616	9516	382
68	9 150973359	1606792997	130075122	3437722	649890	115436	9820	304
69	+10 890503759	+1739530400	+132737403	+2662281	−775441	−125551	−10115	−295
70	12 764522560	1874018801	134488401	1750998	911283	135842	10291	176
71	14 773723174	2009200614	135181813	+693412	1057586	146303	10461	170
72	16 917584633	2143861459	134660845	−520968	1214380	156794	10491	−30
73	19 194204342	2276619709	132758250	1902595	1381627	167247	10453	+38
74	21 600120535	2405916193	129296484	3461766	1559171	177544	10297	156
75	24 130124710	2530004175	124087982	5208502	1746736	187565	10021	276
76	26 777064473	2646939763	116935588	7152394	1943892	197156	9591	430
77	29 531637360	2754572887	107633124	9302464	2150070	206178	9022	569
78	32 382176399	2850539039	95966152	11666972	2364508	214438	8260	762
79	35 314428336	2932251937	81712898	14253254	2586282	221774	7336	924
80	38 311325701	2996897365	64645428	17067470	2814216	227934	6160	1176
81	41 352754078	3041428377	44531012	20114416	3046946	232730	4796	1364
82	44 415316208	3062562130	+21133753	23397259	3282843	235897	3167	1629
83	47 472094831	3056778623	−5783507	26917260	3520001	237158	−1261	1906
84	50 492416438	3020321607	36457016	30673509	3756249	236248	+910	2171
85	53 441618430	2949201992	71119615	34662599	3989090	232841	3407	2497
86	56 280822496	2839204066	109997926	38878311	4215712	226622	6219	2812
87	58 966717374	2685894878	153309188	43311262	4432951	217239	9383	3164
88	61 451354516	2484637142	201257736	47948548	4637286	204335	12904	3521
89	63 681960575	2230606059	254031083	52773347	4824799	187513	16822	3918
90	65 600770999	1918810424	311795635	57764552	4991205	166406	21107	4285
91	67 144889467	1544118468	374691956	62896321	5131769	140564	25842	4735
92	68 246178293	1101288826	442829642	68137686	5241365	109596	30968	5126
93	68 831185381	+585007088	516281738	73452096	5314410	73045	36551	5583
94	68 821113743	−10071638	595078726	78796988	5344892	−30482	42563	6012
95	68 131840035	689273708	679202070	84123344	5326356	+18536	49018	6455
96	66 673989017	1457851018	768577310	89375240	5251896	74460	55924	6906
97	64 353071286	2320917731	863066713	94489403	5114163	137733	63273	7349
98	61 069692033	3283379253	962461522	99394809	4905406	208757	71024	7751
99	56 719839030	4349853003	1066473750	104012228	4617419	287987	79230	8206
100	51 195258394	5524580636	1174727633	108253883	4241655	375764	87777	8547

TABLE OF THE DERIVED FUNCTION bei′ x.

x	bei′ x	Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	Δ_6	Δ_7
0 1	+0 049999974	+	—	—	—	—	—	—
0 2	0 099999167	49999193	—	—	—	—	—	—
0 3	0 149993672	49994505	−4688	—	—	—	—	—
0 4	0 199973334	49979662	14843	−10155	—	—	—	—
0 5	0 249918621	49945287	34375	19532	−9377	—	—	—
0 6	0 299797507	49878886	66401	32026	12494	−3117	—	—
0 7	0 349562345	49764838	114048	47647	15621	3127	−10	—
0 8	0 399146758	49584413	180425	66377	18730	3109	+18	+28
0 9	0 448462528	49315770	268643	88218	21841	3111	−2	−20
1 0	0 497396511	48933983	381787	113144	24926	3085	+26	+28
1 1	0 545807563	48411052	522931	141144	28000	3074	11	−15
1 2	0 593523499	47715936	695116	172185	31041	3041	33	+22
1 3	0 640338102	46814603	901333	206217	34032	2991	50	+17
1 4	0 686008176	45670074	1144529	243196	36979	2947	44	−6
1 5	0 730250674	44242498	1427576	283047	39851	2872	75	+31
1 6	0 772739922	42489248	1753250	325674	42627	2776	96	21
1 7	0 813104947	40365025	2124223	370973	45299	2672	104	8
1 8	0 850926951	37822004	2543021	418798	47825	2526	146	42
1 9	0 885736950	34809999	3012005	468984	50186	2361	165	19
2 0	0 917013613	31276663	3533336	521331	52347	2161	200	35
2 1	0 944181339	27167726	4108937	575601	54270	1923	238	38
2 2	0 966608614	22427275	4740451	631514	55913	1643	280	42
2 3	0 983606691	16998077	5429198	688747	57233	1320	323	43
2 4	0 994428643	10821952	6176125	746927	58180	947	373	50
2 5	0 998268847	+ 3840204	6981748	805623	58696	516	431	58
2 6	0 994262944	− 4005903	7846107	864359	58736	−40	476	45
2 7	0 981488365	12774579	8768676	922569	58210	+526	566	90
2 8	0 9589[illegible]5456	22522909	9748330	979654	57085	1125	599	33
2 9	0 925659305	33306151	10783242	1034912	55258	1827	702	103
3 0	0 880482324	45176981	11870830	1087588	52676	2582	755	53
3 1	0 822297688	58184636	13007655	1136825	49237	3439	857	102
3 2	0 749923691	72373997	14189361	1181706	44881	4356	917	60

33	0 662139131	87784560	15410563	1221202	39496	5385	1029	112
34	0 557689801	104449330	16664770	1254207	33005	6491	1106	77
35	0 435296178	−122393623	−17944293	−1279523	−25316	+7689	+1198	+92
36	0 293662421	141633757	19240134	1295841	16318	8998	1309	111
37	+0 134686760	162175661	20541904	1301770	−5929	10389	1391	82
38	−0 052526621	184013381	21837720	1295816	+5954	11883	1494	103
39	0 259654097	207127476	23114095	1276375	19441	13487	1604	110
40	0 491137441	231483344	24355868	1241773	34602	15161	1674	70
41	0 748166860	257029419	25546075	1190207	51566	16964	1803	129
42	1 031862169	283695309	26665890	1119815	70392	18826	1862	59
43	1 343251997	311389828	27694519	1028629	91186	20794	1968	106
44	1 683250947	339998950	28609122	914603	114026	22840	2046	78
45	2 052634662	369383715	29384765	775643	138960	24934	2094	48
46	2 452012698	399378036	29994321	609556	166087	27127	2193	99
47	2 881799197	429786499	30408463	414142	195414	29327	2200	7
48	3 342181300	460382103	30595604	−187141	227001	31587	2260	60
49	3 833085297	490903997	30521894	+73710	260851	33850	2263	+3
50	4 354140518	521055221	30151224	370670	296960	36109	2259	−4
51	4 904640985	550500467	29445246	705978	335308	38348	2239	−20
52	5 483504900	578863915	28363448	1081798	375820	40512	2164	−75
53	6 089232022	605727122	26863207	1500241	418443	42623	2111	−53
54	6 719859076	630627054	24899932	1963275	463034	44591	1968	−143
55	7 372913333	653054257	22427203	2472729	509454	46420	1829	−139
56	8 045364552	672451219	19396962	3030241	557512	48058	1638	−191
57	8 733575532	688210980	15759761	3637201	606960	49448	1390	−248
58	9 433251539	699676007	11465027	4294734	657533	50573	1125	−265
59	10 139388963	706137424	6461417	5003610	708876	51343	770	355
60	10 846223584	706834621	−697197	5764220	760610	51734	+391	379
61	11 547178908	700955324	+5879297	6576494	812274	51664	−70	461
62	12 234815078	687636170	13319154	7439857	863363	51089	−575	505
63	12 900778962	665963884	21672286	8353132	913275	49912	1177	602
64	13 535756059	634977097	30986787	9314501	961369	48094	1818	641
65	14 129424979	593668920	41308177	10321390	1006889	45520	2574	756
66	14 670415288	540990309	52678611	11370434	1049044	42155	3365	791
67	15 146269645	475854257	65135952	12457341	1086907	37863	4292	927
68	15 543411199	397141574	78712803	13576851	1119510	32603	5260	968
69	15 847117337	−303706135	+93435416	14722613	1145762	+26252	−6351	−1091

TABLE OF THE DERIVED FUNCTION ber′ x—continued.

x	ber′ x	Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	Δ_6	Δ_7
7 0	16 041500948	194383611	109322527	15887111	1164498	18736	7516	1165
7 1	16 109500472	−67999524	126384087	17061560	1174449	+9951	8785	1269
7 2	16 032880103	+76620369	144619893	18235806	1174246	−203	10154	1369
7 3	15 792241582	240638521	164018152	19398259	1162453	11793	11590	1436
7 4	15 367049168	425192414	184553893	20535741	1137482	24971	13178	1588
7 5	14 735669404	631379764	206187350	21633457	1097716	39766	14795	1617
7 6	13 875427436	860241968	228862204	22674854	1041397	56319	16553	1758
7 7	12 762681701	1112745735	252503767	23641563	966709	74688	18369	1816
7 8	11 372918911	1389762790	277017055	24513288	871725	94984	20296	1927
7 9	9 680871288	1692047623	302284833	25267778	754490	117235	22251	1955
8 0	7 660658137	2020213151	328165528	25880695	612917	141573	24338	2087
8 1	5 285953834	2374704303	354491152	26325624	444929	167988	26415	2077
8 2	−2 530184402	2755769432	381065129	26573977	248353	196576	28588	2173
8 3	+0 633245148	3163429550	407660118	26594989	+21012	227341	30765	2177
8 4	4 230690530	3597445382	434015832	26355714	−239275	260287	32946	2181
8 5	8 287972731	4057282201	459836819	25820987	534727	295452	35165	2219
8 6	12 830045258	4542072527	484790326	24953507	867480	332753	37301	2136
8 7	17 880621959	5050576701	508504174	23713848	1239659	372179	39426	2125
8 8	23 461763385	5581141426	530564725	22060551	1653297	413638	41459	2033
8 9	29 593419765	6131656380	550514954	19950229	2110322	457025	43387	1928
9 0	36 292928801	6699509036	567852656	17337702	2612527	502205	45180	1793
9 1	43 574466676	7281537875	582028839	14176183	3161519	548992	46787	1607
9 2	51 448450842	7873984166	592446291	10417452	3758731	597212	48220	1433
9 3	59 920893462	8472442620	598458454	6012163	4405289	646558	49346	1126
9 4	68 992704594	9071811132	599368512	+910058	5102105	696816	50258	912
9 5	78 658944634	9666240040	594428908	−4939604	5849662	747557	50741	483
9 6	88 908025785	10249081151	582841111	11587797	6648193	798531	50974	−233
9 7	99 720862895	10812837110	563755959	19085152	7497355	849162	50631	+343
9 8	111 069974344	11349111449	536274339	27481620	8396468	899113	49951	680
9 9	122 918534244	11848559900	499448451	36825888	9344268	947800	48687	1264
10 0	135 219377774	12300843530	452283630	47164821	10338933	994665	46865	1822

Seismological Investigations.—Seventeenth Report of the Committee, consisting of Professor H. H. TURNER (*Chairman*), Mr. J. MILNE (*Secretary*), Mr. C. VERNON BOYS, Sir GEORGE DARWIN, Mr. HORACE DARWIN, Dr. R. T. GLAZEBROOK, Mr. M. H. GRAY, Mr. R. K. GRAY, Professor J. W. JUDD, Professor C. G. KNOTT, Professor R. MELDOLA, Mr. R. D. OLDHAM, Professor J. PERRY, Mr. W. E. PLUMMER, Dr. R. A. SAMPSON, *and* Professor A. SCHUSTER. (*Drawn up by the Secretary.*)

[PLATES I. AND II.]

CONTENTS.

I. *General Notes.*

THE above Committee seek to be reappointed with a grant of 60*l.*

During the last year the expenditure in connection with seismological work exceeded 320*l.* Out of this sum 200*l.* had kindly been placed at the disposal of your Secretary by the Government Grant Committee of the Royal Society. This covered the salaries of two assistants, without whom it would not have been possible to carry out the work at Shide and that connected with fifty co-operating stations.

Registers.—During the last year Circulars Nos. 24 and 25 have been issued. They refer to Shide, Kew, Bidston, Guildford, Stonyhurst, West Bromwich, Haslemere, Edinburgh, Paisley, Eskdalemuir, Ponta Delgada, St. Vincent, San Fernando, Rio Tinto, Valetta, Cairo, Mauritius, Cape of Good Hope, St. Helena, Ascension, Fernando Noronha, Seychelles, Lima, Baltimore, Toronto, Victoria, B.C., Alipore, Bombay, Kodaikanal, Colombo, Cocos Island, Tokyo, Honolulu, Perth, Sydney, Wellington.

Many of the Registers are received monthly. On arrival, the commencement and maximum of each disturbance they record are entered on a sheet opposite the date on which they were noted, and beneath the name of the station to which they refer. A glance at this table shows

whether a given earthquake was noted at only one or at several stations In the former case the original entry is rejected, and these uncorroborated entries are frequently so numerous that registers have to be recopied before they are passed on to the press. All entries in the circulars, therefore, refer to disturbances which have affected large areas If this course were not pursued the list of local earthquakes for many districts would contain possibly one thousand or more entries per year Another reason for not publishing local disturbances is that a catalogue of this description is prepared by the International Seismological Association

Visitors —The largest party of visitors to the Observatory at Shide was some seventy members of the British Association Among others who came for instruction or to obtain special information were the following: Dr E Naumann, from Frankfurt, Dr F Omori, Major A J. Peile, R A , R C Franck, University of Paris, Maxwell Hall, from Jamaica, Professor J Perry, W E Plummer, Professor J W Gregory, J J. Shaw, E T Cottingham, who kindly put our regulator in order; Hon H Lockward, from Bermuda, Sir William Crookes, Mrs L H Hoover, M H Gray, J Woodrow, Jun , Rev F E Pigot, S J , Professor H H Turner, Professor T Swain

Stations —Paisley At the Coats Observatory arrangements are being made for the installation of a twin-boom seismograph

A new station is to be established at Accra on the Gold Coast

Records are now being received from the Seychelles and Cocos, and shortly it is expected that records will be received from Fiji

Situation of Stations.

Zikawei.—This station is on a plain of alluvium as flat as the sea, extending in certain directions 30 km and in other directions more than 100 km The alluvium is said to be about 100 metres deep Two Omori pendulums are fixed each on a block of concrete (0 80×1 00 ×1 80 metres) A Wiechert astatic seismometer of 1,000 kilogrammes is on a similar block (1 00×1 45×1 65 metres) Water is found in the ground at a depth of 1·5 to 2 metres The building (which is the old magnetic room) is composed of two concentric rooms to avoid effects due to rapid variations of temperature It is 10 kilometres distant from Shanghai and far away from a public road The terminus of the tramways on the Zikawei road is about 800 metres distant

Agincourt —This station is nine miles from Toronto It is on alluvial soil of very considerable depth The underlying rocks at Toronto and Agincourt are the same (Hudson River Shale) The drift deposits no doubt are different to some degree, but there are no sections from Agincourt to compare with those at Toronto

II. *Seismic Activity*, 1904 *to* 1909 *inclusive*

The following catalogue is continuous with the one in the British Association Report for 1911, p 57. The earthquakes to which it refers have been recorded at stations all over the world, or at stations repre-

senting an area of not less than two continents. The number given to an earthquake corresponds to that which is given to the same disturbance in the Shide Register published in British Association circulars On the map, a number underlined means that it was recorded all over the world, but if it is not underlined means that it only disturbed a hemisphere For the methods in which the positions of origins have been determined reference must be made to the British Association Report, 1911 When the time at which an earthquake originated is followed by *plus* or *minus* so many minutes, this means that there is a corresponding uncertainty in the position of its origin The names of places at which an earthquake has been felt are followed by the letter F If destruction has taken place, this is indicated by the letter D The dotted lines on the map are the axes or troughs of districts from which megaseisms have radiated

Date		No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1904			h m			
Jan	7	804	14 50*ca*	M_1	175 E 50 S	
,,	10	805	2 46	F_1	155 E 7 S	
,,	20	806	14 50±2	B	82 W 7 N	Costa Rica and Panama, F.
,,	29	807	0 6±3	F_1	143 E 3 N	
Feb	4	810	20 40±2	D_1	85 W. 1 S	
Mar	1	820	16 10±2	M_2	178 W 13 S	
,,	4	823	10 19±3	D_1	76 W 12 S	Lima, D
,,	16	823*b*	7.25*ca*	F_1	160 E 0 N S	Determined from Manila, Batavia, Christchurch and Honolulu
,,	19	826	6 28±2	D_2	71 W 29 S	Chile, Vallenar, D
,,	31	832	2 16±1	K_3	89 E 31 N	
,,	31	833	5 45±1	K_3	89 E 31 N	
April	4	834	10 3 10 26	K_7	23 E. 42 N	Macedonia, Kossovo and Salonika, D
,,	5	835	10 20	K_2	105 E. 30 N	China, Ssuchuan, D Also Taichu, Formosa, 10·20, F
,,	10	836	8 51 5	K_7	23 E 42 N	
,,	11	837	13 55*ca*	F_1	165 E 13 S	
,,	12	838	18 48*ca*	P	175 W. 44 N	
,,	14	839	1 8±3	F_1	135 E 15 N	
,,	24	841	6 38	E_3	126 E 23 5N.	Formosa, Tainan, D
May	1	845	6.37*ca*	M_1	178 W 33 S	
,,	1	847	15 24*ca*	F_1	130 E 2 N	Ceram, Amahei, at 15 29, F
,,	1	848	23 20*ca*	F_1	130 E. 2 N	
,,	14	851	14 0*ca*	P	170 W 47 N.	
June	7	857	8 15	E_1	144 E 38 N	
,,	18	857*c*	6 6*ca*	M_3	139 W. 14 S.	
,,	24	858	1 4	E_1	160 E 53 N.	Petropaulovski, F.
,,	25	859	14 46	E_1	160 E 53 N	,,
,,	25	860	21 1	E_1	160 E 53 N	,,
,,	26	861	10 41	E_1 PQ	166 E 42 N	,,
,,	27	863	0 10	E_1	160 E 53 N	,,
July	1	865	13 29	E_1	148 E 42 N	
,,	10	869	23 0*ca*	H	45 W. 10 N.	

Seismic Activity—continued

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1904		h m			
July 23	870	0 28	F_2	133 E 5 S	Fak-Fak, New Guinea, F Perth record does not agree
,, 24	872	10 45±3	E_1	160 E 53 N	Petropaulovski, F
,, 27	873	5 20	K_3	72 E 33 N	
,, 27	874	15 30	M_2	179 E 2 N	
Aug. 8	877	22 49 3	M_1	179 E 42 S	Wellington, New Zealand, F
,, 11	878	6 6	K_5	27 E 38 N.	Samos, D
,, 14	879	2 49	M_1	180 E 40 S	New Zealand, Waipawa, F
,, 18	881	4 42	F_2	119 E 10 S	Bima and Lombok, F
,, 18	882	20 5 5	K_5	27 E 38 N	Samos, Chios, Smyrna, F
,, 24	884	21 0	E_3	135 E 32 N	
,, 27	885	21 56±2	A_1	141 W 67 N	
,, 30	886	11 41	K_3	101 E 30 N	Tachien lu, Ssuchuan, D
Sept 8	888	2 29	F_1	135 E 8 N	
,, 11	889	5 48±3	K_3	106 E 23 N	
,, 13	890	17 5±5	M_1	170 W 32 S	
,, 19	892	4 56	M_1	180 E 20 S	
,, 25	895*b*	15 10*ca*	M_1	160 E 40 S	
,, 27	896	15 9*ca*	G_1	38 E 38 S	
Oct 1	898*b*	10 10	E_3	126 E 7 N	Caraga, Davao, Cotabato, D
,, 2	899	21 50	E_1	160 E 50 N	
,, 3	900	3 3	G_1	61 E 7 N	
,, 8	903	18 36	E_3	122 E 18 N	Ilocos Norte and Cagayan, D
,, 9	904	13 51	J	15 W 70 N	Another earthquake near Wellington, at 13 58, Namdalam, Norway, at 14 0, also Quito, at 14 15, F
,, 28	911	13 51	F_3	113 E 8 S	E Java, Batoe, in Pasoervean, D
Nov 5	918	20 25	E_3	120 E. 23 N	Time and origin given by Omori, Formosa, D
,, 6	919	4 20±2	E_3	120 E 27 N	
,, 21	922*b*	3 20	M_1	167 E 39 S	
,, 22	923	1 7	F_1	157 E 2 N	
,, 23	923*b*	16 37	G_1	32 E 39 S	
Dec. 2	924	1 30*ca*	E_3	132 E 10 N	Origin determined from Manila, Batavia and Christchurch
,, 2	924*b*	2 19	B	85 W 7 N	
,, 4	925	10 23*ca*	O	30 E 10 S	
,, 11	930*b*	17 3	D_2	68 W 30 S	Santiago to Valparaiso, F. Centre at Vallener.

Seismic Activity—continued

Date		No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1904			h m			
Dec.	19	937	17 43	M_1	162 E 57 S.	
,,	20	938	5 44*ca*	B	83 W 12 N.	Nicaragua, Costa Rica, Panama, Port Limon, D
1905						
Jan	9	948	6 17	K_4	46 E 38 N	Szirtes gives origin S E of Tiflis.
,,	13	949	13 18±2	F_1	143 E 0 N S	
,,	20	952	2 32	K_7	22 E 40 N	Aghuia, Greece, F
,,	20	953	18 1±2	B	82 W 13 N	
,,	20	954	22 27*ca*	F_2	123 E 7 S	
,,	22	955	2 42	F_1	123 E 3 N	Zamboanga, F
,,	29	956	12 45*ca*	H	16 W 53 N	
Feb	2	957*b*	21 4*ca*	F_1	93 E 7 S	
,,	4	958*b*	6 26	K_3	108 E 6 N	
,,	13	960	5 16*ca*	F_1	146 E 2 S	
,,	13	960*b*	23 31*ca*	F_1	157 E 35 S	
,,	14	961	8 50	Q	180 E 35 N	
,,	17	963	11 42	K_3	96 E 26 N	
,,	19	964	4 35±3	F_1	168 E 10 S	
,,	26	965	2 26	F_1	170 E 14 S	
,,	27	966	17 25	M_1	176 W 23 S	
Mar	4	967	16 0±2	F_1	158 E 2 S	
,,	4	968	18 30	F_3	158 E 2 S	
,,	4	969	23 15±2	F_1	142 E 2 N	
,,	14	973	10 41	K_2	72 E 40 N	
,,	17	975*b*	22 14	H	32 W 33 N	
,,	18	977	23 56	M_2	168 E 10 S	
,,	22	980	3 40±2	Q	173 5 E 40 N	
April	4	982	0 48	K_3	76 E 32 N	Kangra Valley, D
,,	10	984	12 3	E_3	120 E 23 N	
,,	19	986	12 25	M_1	171 W 32 S	Origin given by Szirtes
,,	24	988	8 6	E_3	124 E 12 N	Masbate, S E Luzon F
	25	989	9 13±2	M_2	177 E 3 N	
,,	26	990	21 42±2	D_1	70 W 19 S	
,,	29	993	0 47	K_7	7 E 46 N	
May	9	995	6 43	B	105 W 20 N	Autlan, E of Jalisco, Mexico, F
,,	11	996	17 5±2	E_2	144 E 21 N	
,,	12	997	2 45±5	D_1	76 W 10 S	
,,	12	998	15 30±5	D_1	77 W 12 S	Batanes Is felt at 16 49
,,	18	1001	13 42	F_1	149 E 4 S	Origin given by Szirtes
,,	23	1004*b*	7 1±8	G_2	83 E 12 S	
,,	31	1008	18 21	E_3	126 E 12 N	
June	1	1009	4 40	K_7	19 E 42 N	
,,	2	1010	5 39	E_3	132 5 E 34 N	Kyushu, Shikoku, F
,,	9	1018	12 22±2	M_2	160 E 3 N	
,,	12	1020	5 13*ca*	M_2	168 E 5 S	
,,	14	1021	11 25±3	M_3	153 W 30 S	
,,	30	1025	17 6±2	F_1	167 E 16 S	
,,	30	1026	19 46±2	D_1	100 W 12 S	
July	6	1031	16.18	E_1	144 E 39 N	N E Japan, F.

Seismic Activity—continued

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1905		h m			
July 9	1036	9 39	K_1	98 E 50 N	
,, 11	1038	8 38	K_1	101 E 47 5 N	
,, 11	1039	15 37	E_1, E_2	140 E 34 N	
,, 14	1045	8 50	A_1	142 W. 56 N	
,, 14	1046	22 0	K_1	98 E 50 N	
,, 16	1047	18 50*ca*	F_3	87 E 8 S	
,, 17	1048	0 22*ca*	F_1	171 E 18 S	
,, 23	1052	2 45	K_1	98 E 50 N	
,, 27	1054	22 19±2	E_3	130 E 7 N	Southern part of Samar, Leyte, F
Aug 4	1057	5 9*ca*	K_7	19 E 41 N	
,, 25	1063*b*	9 45±3	E_3	135 E 39 N	
Sept 1	1063*c*	2 36*ca*	E_2	148 E 20 N.	Origin determined from Manila, Zika wei, Honolulu and Tashkend Ten minutes later there was an earthquake in Japan, Aomori to Iida, F
,, 8	1064	1 43	K_6	16 E 39 N	Calabria, D
,, 14	1065	19 41	E_1	160 E 40 N	
,, 15	1066	5 57	E_1, P	164 E 53 N	Origin given by Szirtes
,, 26	1070	1 29	K_3	73 E 30 N	
,, 29	1071	11 50	F_1	131 E 8 S	
Oct 8	1074	7 27	K_7	23 E 42 N	Bulgaria, F
,, 14	1075*b*	14 37*ca*	C_1	76 W. 19 N	Cuba, Santiago, F
,, 15	1076	21 42	C_1	68 W 24 N	
,, 21	1077	11 1	K_4	42 E 42 N	
,, 21	1078	13 20	K_4	42 E 42 N	
,, 24	1082	17 40±2	Q	130 W 15 N	
Nov 6	1086	16 51±2	F_1	146 E 0 N S	
,, 8	1087	22.6	K_7	24 E 40 N	Macedonia, Mt Athos, D
,, 21	1092*a*	21 50*ca*	F_1	165 E. 10 S	
,, 21	1092*b*	23 5	G_2	80 E. 0 N S	
,, 21	1092*c*	23 45*ca*	G_2	70 E 10 S	
Dec 4	1096	7 5	K_5	39 E 39 N	Malatia Asia Minor, D
,, 4	1096*b*	9 40	K_5	39 E 39 N.	
,, 10	1097	12 30	P	160 W. 50 N	
,, 10	1098	18 6	E_3	130 E 5 N.	Mindanao and Visayas, F
,, 17	1101	5 27	B	113 W. 17 N	
,, 17	1102	9 34	B	113 W. 17 N	
1906					
Jan 3	1107	1.54±4	F_1	169 E 15 S.	
,, 6	1109*b*	21 27±3	E_1	167 E. 54 N.	Petropaulovski, F
,, 10	1110	13 2±2	A_1	146 W. 40 N.	
,, 15	1110*b*	19 27	F_3	97 E 0 N S.	Padang, F.
,, 21	1111	13 46	E_2	143 E 34 N.	Origin given by Omori, E. coast of Japan, F.
,, 22	1111*b*	4.2±2	F_1, M_2	168 E 13 S.	
,, 24	1112*a*	6.40	A_1	139 W. 50 N.	

Seismic Activity—continued.

Date		No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1906			h m			
Jan.	24	1112*b*	21 35±2	A_1	130 W. 55 N.	
,,	27	1114	21.33±3	E_1, P, Q	168 E 42 N	
,,	28	1116	14 33±2	E_2	140 E 26 N	Tokio, F
,,	31	1118	15.33	D_1	80 W 1 N.	Columbia, Pacific Coast, D.
Feb	1	1120	2 16±2	M_2	170 E 12 S	Origin determined from Christchurch, Perth, Honolulu, Batavia, Manila and Tokio Another earthquake occurred in Europe at nearly the same time
,,	2	1122	16 43±3	D_1	84 W 8 S	Tumaco, F
,,	5	1124	4 15	M_3	152 W. 35 S	
,,	10	1124*c*	8 47±2	F_2	128 E. 4 S	
,,	16	1126	17 35	C_1	59 W 17 N	It broke cables
,,	19	1128	1 58±2	M_2	170 E 10 S	
,,	23	1129*b*	15 14	E_2	149 E 31 N	Awa Kazusa, F
,,	24	1130	0 12	E_2	140 E 31 N	,, ,,
,,	27	1133	19 40	K_3	79 E 30 N	Rampur, D.
Mar	2	1135	6 16	K_2	77 E 38 N.	Jarkent, F.
,,	3	1135*b*	8 35*ca*	D_1	90 W 2 N	
,,	8	1136	17 43±2	H	20 W 40 N	
,,	9	1137	19 24±4	F_1	172 E 20 S	
,,	10	1138	6 30±5	M_3	158 W 28 S	
,,	10	1139	16 18±2	M_3	160 W 30 S	
,,	11	1141	8 36±3	M_3	162 W 28 S	
,,	13	1143	13 19±2	E_3	133 E 30 N	
,,	16	1145	22 42	E_3	120 5 E 23 5 N	Formosa, D Origin given by Omori.
,,	19	1146	7 57	J	9 W 70 N	
,,	20	1146*b*	1 53±2	F_1	145 E 5 S	
,,	20	1147	3 48*ca*	K_5	27 E 33 N	
,,	26	1150	3 28	E_3	120 E 23 5 N	
,,	27	1152*a*	5 0	L	55 W 52 S	Origin determined from Cordova, Christchurch and Mauritius The distance apart of these origins is 156°
,,	27	1152*b*	5 23±2	J	120 E 78 N.	Origin determined from Cairo, Bombay, Shide, Honolulu and Beirut
,,	27	1152*c*	22 53	E_3	119 E 25 N.	Tainan, F
,,	28	1154	18 0	M_3	152 W. 32 S	
,,	29	1156	21 44±2	B, D_1	85 W. 7 N.	
April	5	1160	22 20*ca*	F_1	147 E. 0 N.S.	
,,	8	1163	17 30±2	E_2	142 E 25 N.	
,,	10	1164	21.18	A_2, B	110 W 20 N	
,,	13	1166	19 17	E_3	120.5 E 23 N.	Formosa, D.
,,	14	1168	3.44*ca*	M_3	140 W. 32 S.	Tanna, New Hebrides, F.

Seismic Activity—continued

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1906		h m			
April 18	1170	13 12	A_2	121 W 38 N	California, D
,, 19	1171	6 54*ca*	F_1	168 E 9 S	
,, 23	1172	9 10	A_2	123 W 42 N	Grant Pass, Oregon, Berkley, California, F
,, 25	1175	1 30	E_3	126 E 7 N	Caraga, Davao, Cotabato, S E Mindanao, F.
,, 29	1181	16 20*ca*	G_2	82 E 40 S	
May 2	1182	1 12	E_3	124 E 23 N	Ishigakijima, F
,, 5	1183	0 18±2	D_1, D_2	71 W 20 S	Arica, F
,, 12	1184	5 50±2	K_3	92 E 28 N	
,, 12	1185	10 38	E_1	155 E 42 N	
June 1	1190	4 30±2	F_1	145 E 0 N S	
,, 2	1191	14 20	F_1	153 E 5 S	
,, 10	1195	20 50	G_2	85 E 3 S	
,, 19	1199	11 21±2	E_3	128 E 20 N	
,, 20	1203	2 25±2	B	89 5 W 13 5 N	San Salvador (the capital), F An eqke originated N Luzon about 3 41 or 1h 16m later The time taken to travel from Salvador would be 1h 23m Therefore the large waves from Salvador 132° may have caused the Manila eqke
,, 22	1205	3 17	B	95 W 17 N	Mexico, Chiapas, F
,, 24	1208	11 20	F_3	91 E 5 N	
July 10	1219*b*	19 40±2	E_3, F_1	128 E 6 N	S of Agusan River Valley, F
,, 13	1220	23 42±2	H	34 W 16 N	
,, 20	1225	11 16±2	H	33 W 8 N	
,, 22	1226	18 30±2	G_1	63 E 29 S	
Aug 1	1232	23 20	Q	155 E 23 N	
,, 9	1237	11 0±3	F_1	170 E 12 S	
,, 15	1240	22 2±2	K_2	95 E 44 N	Russian Turkestan, F
,, 17	1242	0 6±2	Q	168 E 31 N	
,, 17	1242*b*	0 41	D_2	72 W 33 S	Valparaiso, D See Brit Assoc Seis Report, 1911.
,, 18	1246*b*	6 45±3	M_3	157 W 30 S	
,, 19	1248	9 27*ca*	D_2	72 W 33 S	After-shock of 1242*b* Valparaiso, F
,, 19	1248*b*	15 34*ca*	D_2	72 W 33 S	After-shock of 1242*b* Valparaiso, F
,, 21	1252	11 15±2	D_2	76 W 45 S	
,, 21	1253	20 43±2	H	21 W 42 N	
,, 22	1254	19 41	M_1, F_1	165 E 34 S	
,, 24	1255	1 58*ca*	C_2	73 W 4 N	
,, 25	1256	11 51±2	O	33 E 4 N	Addis Abeba in Abyssinia, F.
,, 25	1257	13 47±2	O	33 E 4 N	After-shock of 1256.

Seismic Activity—continued

Date		No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1906			h m			
Aug.	26	1258	6 0±2	F_1	146 E 0 N S	
,,	28	1261	5 9	B	107 W 8 5 N	
,,	30	1263	2 33±2	D_2	75 W 23 S	Tacna, Arica, and Iquique, F.
,,	31	1264	14 58	K_3	95 E 21 N	
Sept.	6	1265*b*	19 2*ca*	M_1	178 W 34 S	
,,	7	1266	18 51	E_1, E_2, E_3	145 E 35 N	Japan and Manila, F
,,	14	1271	13 12*ca*	L	23 E 69 S	
,,	14	1272	16 0±2	F_1	148 E 4 S	
,,	17	1274	4 15	E_1, E_2, E_3	145 E 35 N	Tokio, F
,,	17	1275	8 36	F_1	148 E 4 S	
,,	20	1277	17 24*ca*	D_2	81 W 29 S	
,,	21	1278	1 30*ca*	M_3	157 W 20 S	
,,	28	1281	15 23*ca*	D_2	82 W 12 S	P_1 for Cordova, Trinidad, Honolulu, Victoria, B C, and Shide agree with time at origin
Oct	2	1284	1 50±2	F_1	152 E 2 N	Buna Bay with sea waves, F
,,	2	1285	14 17±3	L	10 W 79 S.	
,,	6	1286	12 34	F_3	98 E 11 S	Origin determined from Batavia, Perth, Colombo and Kodaikanal
,	10	1289	7 21	E_3	128 E 12 N	Surigao and Caraga, F
,,	10	1290	12 52±2	E_3	125 E 9 N	Surigao and Caraga, F
,,	10	1291	23 19	K_8	7 E 32 N	Origin determined from Cairo, Tiflis, Rome and Edinburgh
,,	11	1291*b*	5 9	F_1	155 E 10 S	
,,	15	1292*b*	13 23	F_1	177 E 22 S	
,,	17	1292*c*	9 41	E_3	126 E 16 N	Luzon, F
,,	24	1293	14 41	K_2	73 E 38 N	Samarkand, Khojent, Karki, Kelif, &c ,F
,,	28	1293*b*	15 47	F_3	101 E. 13 S	S W Java and Sumatra, F
,,	29	1294	1 9	F_1	132 E 1 N	Origin determined from Manila, Batavia, Honolulu and Perth
,,	31	1296	1 46±2	K_1	140 E. 55 N.	
Nov	5	1297	19 45±2	F_1	132 E 3 S	Fak-Fak, F
,,	5	1297*b*	22 57	F_1	125 E 0 N S	
,,	8	1299*a*	0 39	E_1, E_2, E_3	144 E 33 N	
,,	10	1299*b*	5 3±2	F_1	160 E 10 S	
,,	12	1300	17 33	K_2	83 E 44 N.	
,,	14	1301	17 35±2	F_1	170 E 10 S	
,,	19	1303	7 16±2	F_3 (S of)	111 E 22 S	W Australia, Albany to Shark's Bay, F.
,,	28	1305	8 58±2	D_2	82 W. 23 S.	

Seismic Activity—continued

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1906		h m			
Dec. 3	1307	22 58	C_1	57 W 15 N	George Town, F. Origin determined from Porto Rico, Toronto, San Fernando, measured by commencement of Large Waves.
„ 18	1318	20 58±2	M_1, M_2	172 W 19 S.	
„ 19	1319	1.13	M_1, M_2	172 W. 18 S	Tonga and Apia, F
„ 22	1320	18 21	K_2	86 E 44 N	Manass, Urumtsi (N.W. China), D Kopal, Semiretchensk, F
„ 23	1321	7 0±2	P	163 W 51 N	
„ 23	1322	17 16±2	P	163 W 51 N.	-
„ 26	1323	5 54	D_1, D_2	73 W 20 S	Arica, F, observation agrees with Cordova and Trinidad. Com. of L W. agrees with Cheltenham, U S A, Azores, San Fernando, Bidston and Shide
„ 26	1323*a*	6 4±2	H	18 W 38 N	Origin determined from Azores, San Fernando, Bidston, Messina and Rome
1907					
Jan 1	1324	0 20±4	F_2	140 E 12 S	
„ 2	1327	11 57	M_1	180 E 10 S	There was a second shock about 14 30 or 12 43, Tonga, F
„ 4	1328	5.17±1	F_3	95 E 2 N	Simalur, Nias, Sumatra, D
„ 7	1330	13 54±4	M_1	160 E 32 S	
„ 8	1331	5 10±5	L	30 W 65 S	
„ 12	1332*b*	7 45±5	K_1	180 E 70 N	N E end of K_1, or 157 W 55 N.
„ 14	1333	15 26	C	76 W 18 N	Jamaica, Kingston, D
„ 19	1334	13 9	K_1	130 E 50 N	Alexandrovsky, F
Feb 3	1334*b*	6 14	F_1	122 E 0 N S	Gorontalo and Celebes, F
„ 3	1335	19 25±5	M_2	147 E 12 N	Wareo, N. Guinea, F.
„ 16	1342	21 14±1	F_1	175 E 10 S	
„ 24	1347	7 10±5	L	55 E 65 S	
Mar 19	1350*b*	22 2±1	F_1, F_2	126 E 0 N S	N E Celebes, F
„ 26	1350*c*	11 18±1	E_2	140 E 30 N	
„ 27	1350*d*	0 14±2	L	10 W 55 S	
„ 29	1351	20 44	F_1	128 E 7 N	Caraga, Talou Is and N Celebes, F Origin determined from com of Manila, Zikawei, Calcutta, Honolulu, Samoa, and Shide records

Seismic Activity—continued

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1907		h. m			
Mar. 29	1351*b*	20.53*ca*	K_3	70 E 35 N	Origin determined from the max of Calcutta, Kodaikanal, Irkutsk, and Shide records Also agrees with Verny and Tiflis Perth and Sydney also suggest third eqke at 110 E 60 S Time, 20 46*ca*
,, 31	1351*c*	14 12±2	K_5	50 E 30 N	
,, 31	1352	21 49±2	F_1, M_2	167 E 5 S	Tonga, F
April 13	1359*b*	17 53	K_3	72 E 38 N	Ferghana, F
,, 15	1361	6 4±1	B	99 W 16 N	Guerrero, Mexico, D
,, 18	1362	20 59	F_1, E_3	124 E 13 N	Camarines, D
,, 18	1363	23 53	F_1, E_3	123 E 13 N	,, ,,
,, 24	1366*b*	23 24±1	F_1	135 E 5 S	Elat, Gt Kei Is and Merauke, S New Guinea, F
May 3	1369	20.34	E_3	121 E 17 N.	N Luzon, F.
,, 4	1371	5.45±2	E_2, M_2	153 E 10 N.	Namatani, N. Guinea, F.
,, 4	1372	8 35±2	E_2	150 E 23 N	
,, 7	1375	10 15±1	E_3	130 E 23 N	
,, 13	1379	20 50±3	F_1	150 E 10 S	New Guinea, F.
,, 20	1381	7 45 5	E_3	126 E 10 N	N E Mindanao and Leyte, F
,, 22	1384	22 52	E_1	142 E 37 N	Rikuzen, F
,, 25	1386	11 53	E_2, M_2	138 E 13 N	Borneo, F.
,, 25	1387*a*	13 58±2	E_1, E_3	125 E 24 N	
,, 25	1387	14 7 5	H	35 W 12 N	Another eqke at Bonin Islands at 14 4*ca*
,, 25	1388	15 52±2	E_1, E_3	125 E 24 N	N Luzon, D
,, 31	1389	12 45	F_1	161 E 5 S	Tonga, F
June 1	1390	8 45±3	D_1	82 W 0 N S	Guayaquil, Ecuador, F
,, 5	1393	3 18±3	D_1	86 W 0 N S	Guayaquil, Ecuador, F
,, 13	1398	9 18±2	D_2	80 W 38 S	Valdivia Chile, F
,, 24	1404	3 31±1	E_2	140 E 14 N	Celebes, F.
,, 25	1405	17 56	F_1	126 E 1 N	Menado and N Celebes, F.
,, 26	1405*b*	4 50	E_2	140 E 20 N	
,, 26	1405*c*	17 15±2	E_2	140 E 20 N	
,, 27	1406	22 26±1	F_1	170 E 3 S	New Hebrides F.
July 1	1408	13 6±3	D_1	105 W 0 N S	Honduras, F.
,, 4	1409	9 21	K_5	55 E 27 N	
,, 9	1414	18 52	E_3	123 E 13 N	S Luzon and Visayas Is, F
,, 12	1415	17 20	K_3	72 E 26 N	
,, 20	1419	13.33	E_3	126 E 7 N	Mindanao, F
,, 29	1422	0 51±4	G_1	28 E 38 S	
,, 29	1425	19 27	F_1	120 E 0 N S	Menado, D.
Aug 5	1427	1 55±1	E_2	140 E 32 N.	Akita, F.
,, 5	1428	6 32±2	D_2	82 W 24 S.	Antofagasta, Chile, F.
,, 9	1431	19.0±2	B, D_1	90 W. 1 N.	

Seismic Activity—continued

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1907		h. m			
Aug. 13	1432*b*	21 36±3	F_1	165 E 3 S	
„ 17	1433	17 21*ca*	G_1	66 E 20 N	Origin determined from Calcutta, Mauritius, Cairo, and Shide
„ 17	1433*a*	17 27	E_1	160 E 50 N	Origin determined from Chita, Honolulu, Shide and Osaka
„ 22	1435	22 14±5	E_1	155 E 38 N	Origin determined from Samoa, Honolulu and Shide Doubtful
Sept 2	1439	16 2±3	Q	166 E 20 N	
„ 2	1439*b*	17 34±2	Q	166 E 20 N	
„ 15	1446	17 45	K_2	72 E 40 N	Khokand, Margelan, and Adishan, F Second shock at 19 12*ca*, Osch, D
„ 22	1448	12 9	E_2	135 E 23 N	
„ 23	1450	21 34±2	B	115 W 16 N	
Oct 2	1453*b*	1 42±2	F_1	167 E 15 S	Origin determined from Christchurch, Sydney, Samoa and Honolulu Another eqke about 13 5, nr Capetown
„ 4	1454	10 27	F_3	103 E 6 S	S E Sumatra and W Java, F
„ 5	1456	3 30	E_3, F_1	122 E 10 N	Panay, Negro Is , F.
„ 10	1458	21 41	M_2	155 E 9 S	
„ 11	1460	14 28	M_2	162 E 5 S	
„ 16	1463	13 55	A_2	115 W 23 N	Guaymas, Mexico, F
„ 17	1464	11 20±2	B	80 W 10 N	
„ 21	1468	4 17	K_3	68 E 39 N	Karatagh, D
„ 23	1471	20 25	K_6	16 E 39 N	Ferruzzano, S Calabria, D Same time at Kerki, Is of Samor
„ 27	1475	5 12	K_2	68 E 40 N	Samarkand, F
Nov 3	1481	19 49±2	F_1, M_2	172 E 13 S	
„ 12	1486*b*	7 0±3	M_1	180 E 23 S	
„ 13	1487	3 12±2	M_2	178 E 10 S	
„ 16	1489	10 10±5	B, D_3	97 W 2 N	Peru, F.
„ 16	1489*b*	22 3	E_3	122 E 14 N	S Luzon, F
„ 19	1491	12 10±2	D_2	75 W 44 S	Punta Arenas, F
„ 19	1492	21 24±2	M_2, E_2	140 E 5 N	
„ 21	1495	20 1	F_3	93 E 0 N S	N.W. Sumatra, F
„ 24	1496	13 58	F_3	123 E ·13 N	Camarines, S E Luzon, D
Dec 5	1505	12 34	F_3	104 E 4 S	S E Sumatra, N W Java, F
„ 5	1506	20 12	F_3	104 E 4 S	S E Sumatra
„ 15	1509	17 32±2	M_2	153 E 5 N	New Guinea
„ 23	1510	1.14	E_1	145 E. 42 N	Kushiro, F.

Seismic Activity—continued

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1907		h. m.			
Dec. 24	1511	13 26±2	H	32 W 12 N.	
,, 25	1513	22 34±1	K_2	77 E. 36 N.	Kokand, F.
,, 30	1515	5 22±2	D_1	97 W 8 S	
1908					
Jan 5	1518	2 6	E_3	124 E 13 N.	Legaspi, S.E. Luzon, F.
,, 11	1522	3 35	E_3	121 E 23 N.	Tainan, Formosa, F Origin determined by Omori
,, 12	1523	10 19*ca*	K_3	70 E 33 N	
,, 15	1526	12 56	E_1	142 E 36 N	Central and North Japan, F
,, 16	1527	9 3±2	E_3	117 E 23 N	Formosa, F.
,, 25	1530	20 6*ca*	O	32 E 15 N	
,, 27	1530*b*	15 52±2	K_2	110 E 31 N	
Feb 1	1532	23 17*ca*	M_3	113 W 2 S	Origin determined from Lima, Pilar, Honolulu and Samoa
,, 1	1532*b*	23 22*ca*	C_1	67 W 26 N	Origin determined from Trinidad, Baltimore, Toronto, Victoria, B C, and Shide
,, 5	1536	22 0	D_2	67 W 23 S	Salta and Tucuman, F
,, 6	1537	1 27*ca*	F_3	100 E 5 S	Southern and Middle Sumatra, F. With sea waves
,, 9	1540	18 13	K_2	100 E 26 N	
,, 14	1544	8 50*ca*	D_1	80 W 5 S	Lima, F Eqkes also in Alaska, Tiflis and Bohemia
Mar 2	1546	20 21	E_1	145 E 30 N	Nemuro, F
,, 5	1549	2 16	F_1, E_3	126 E 9 N	Agusan River Valley, F Six mins later felt at Buitenzorg, Java.
,, 12	1549	19 25	K_2	70 E 36 N	Bokara, F
,, 13	1550	6 18	K_3	100 E 23 N	Mandalay, F
, 15	1553	9 6±3	F_1	174 E. 12 S	
,, 19	1556*a*	3 0*ca*	M	178 E 35 S	
,, 23	1560	12 20±2	F_2	129 E 10 S	Timor, F
,, 23	1560*a*	12 28*ca*	E_3	112 E 22 N	Origin determined from Manila, Tokio, Calcutta and Siberian stations
,, 25	1562	19.0*ca*	M_3	105 W 20 S	Origin determined from Lima, Pilar, and Honolulu.
,, 26	1563	23 2	B	101 W. 17 N	Chilapa, D.
,, 27	1564	3.45 5	B	101 W 17 N.	,,
April 2	1568	5.52±2	O	26 E. 2 N.	
,, 4	1569	6.18	K_3	89 E. 33 N.	

Seismic Activity—continued

Date		No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1908			h m			
April	9	1570	23 52±5	F_2	120 E 7 S.	Apparently three earthquakes.
,,	12	1570*b*	19 2±2	E_2	145 E 20 N	
,,	16	1571	17 38	K_2	69 E 39 N	Pendschikent, Tashkent, F
,,	19	1572	7 58	E_1	142 E 38 N	Central and North Japan, F.
,,	22	1575	23 45±3	G_1	48 E 38 S	
,,	30	1576	4 45	B	85 W 5 N.	San José, Costa Rica, F
May	3	1577	0 50	E_1	155 E 41 N.	North Japan, F
,,	5	1578	6 16±2	E_3, F_1	123 E. 3 N	Basilan Island, F
,,	5	1579	11 19±2	G_2	68 E 12 S	
,,	11	1581	13 44	F_1	119 E 2 N	E Borneo, F
,,	12	1582	20 18	E_2	142 E 32 N	Central Japan, F Another shock at 20 34
,,	15	1585	8 32	A_1	145 W 56 N.	Yakutat, Alaska, D.
,,	17	1587	12 33	K_7	25 E 42 N	
,,	20	1589	7 39	F_2	122 E 5 S.	
June	3	1591	15 56	K_3	67 E 28 N	Quetta, F.
,,	9	1593	2 56	E_1, E_2, E_3	142 E 35 N	Awa, Kazusa, F
,,	27	1595	14 21	E_2	147 E 33 N	Central and North Japan, F
July	1	1596	7 26	E_3	124 E 22 N	Batanes Island, E Formosa and Ishigakijima, F
,,	13	1600	21 6±5	E_1	145 E 35 N	Origin determined from com at Osaka, Irkutsk, Honolulu Agrees with Bombay and Baltimore
,,	26	1601	16 0	F_3	104 E 6 S.	Second shock 17 12, S Sumatra, F
Aug.	12	1604	15 40±3	M_2	160 E 5 S	Origin determined from com of Samoa, Perth, Osaka Agrees with Calcutta, Capetown and Lima records
,,	12	1605	18 39	F_2	130 E 5 S	Banda Island, D
,,	17	1607	10 32±2	L	40 W 60 S	
,,	19	1609	0 29*ca*	D_1	70 W 8 S	Trujillo and Pacasmoya, F
,,	20	1612	9 53	K_2	89 E 32 N	
,,	22	1618	19 8*ca*	M_2	175 E 6 N	
,,	29	1619	18 15±3	H	36 W 36 N	
Sept	4	1620	16.52±1	H	30 W 40 N	
,,	13	1621*b*	4.6	E_2	154 E. 33 N.	N E Japan (Honshu), F
,,	21	1622	6 31	Q	155 W. 19 N.	Puna, Hawaii, F.

Seismic Activity—continued.

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1908		h m			
Sept. 22	1622*b*	2 49	F_1	149 E 6 N.	
" 23	1623	7.7	F_3	90 E 10 N.	
" 26	1627	5 18±2	L	150 E. 60 S.	Origin determined from Christchurch, Sydney, Capetown and Pilar.
" 28	1628	6 28	K_5	44 E 38 N	
Oct 7	1630*a*	0 48±2	F_1	142 E 0 N	
" 13	1632	5 6	B	102 W 18 N	Mexico City, F
" 14	1633	14 54	J	30 E 80 N	Origin determined from Shide, Irkutsk, Victoria, B C, and many other stations
" 20	1634	2 40	E_3	122 E. 16 N	E Luzon, F
" 20	1635	5 37	E_3	122 E 16 N	"
" 23	1636	20 13	K_3	70 E 35 N	
" 24	1637	21 12	K_3	75 E. 36 N	
Nov 2	1638	5 16	F_3	97 E 2 S	Padang and N Sumatra, F Second shock 7 20
" 6	1639	7 12±5	Q	160 E 30 N	S Bonin Island, F.
" 6	1640	13 45±2	P	169 E 51 N	
" 9	1642	15 6	D_2	60 W 23 S	
" 10	1643	18 51	E_3	126 E 9 N	Agusan River Valley, F
" 11	1644	13 18	E_3	121 E 10 N	Panay Island, F
" 12	1644*a*	12 8	D_1	78 W 14 S	Lima, F
" 12	1644*b*	16 37	F_3	98 E 1 S	Batoe Island, D
" 15	1645	1 30	F_2	118 E 4 S	S W Celebes, F.
" 22	1649	7.15	E_1	146 E 42 N	
" 23	1650	12 42±2	K_3	108 E. 11 N	Origin determined from com of Manila, Batavia, Calcutta, and Osaka Agrees with Perth, Tashkent
" 30	1656	21 20	M_1	177 E 37 S	Whale Island, F Origin determined from the com of records from all the world stations, also max for Christchurch
" 30	1656*a*	21 33	E_3	122 E 20 N.	Babuyan Island, F Origin determined from Manila, Zikawei, Irkutsk and Indian stations Distance from 1656 to 1656*a*, 75°. Time taken for P_1 to travel this distance would be 14 min.

Seismic Activity—continued.

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1908		h m			
Nov. 30	1656*b*	21 36	A_1	135 W 55 N	Queen Charlotte Is, F. Origin determined from Victoria, Toronto, Baltimore, Shide and European stations Distance, 1656 to 1656*b*, 100° Time taken for P_1 to travel this distance would be 17 min, and this it practically did Five maxima were recorded at Shide At 22 15 - 22 20 (which refers to the Queen Charlotte Is shock), 22 22–22 23 (which refers to Manila), and 22 53 (which refers to New Zealand).
Dec 12	1659	12 53	K_3	102 E 25 N	
,, 12	1660	18 50±2	F_1	130 E 0 N S.	N W New Guinea, F Origin determined from com of Manila, Batavia, and Sydney
,, 18	1663	15 35	G_1	52 E 17 N	
,, 22	1664	2 41	E_3	121 E 25 N	Formosa, F
,, 28	1670	4 20 4	K_6	15 35 E 38 10 N	Messina, D
1909					
Jan 3	1677	21 40	M_1	151 E 53 S	
,, 15	1692	16 35	F_1, E_3	128 E 8 N.	
,, 21	1695	2 20±3	F_1	169 E 8 S	
,, 23	1701	2 48	K_5	50 E 33 N	Burujird to Ispahan, D
,, 29	1707	0 39±2	F_1	130 E 0 N S	
,, 29	1708	12 43±2	F_1	133 E 5 N	
Feb. 9	1718	11 23	K_5	38 E 40 N	Harpoot and Alexandropol, F.
,, 9	1719	14 38	K_5	38 E. 40 N	Harpoot and Alexandropol, F
,, 10	1721	19 49	K_5	38 E 40 N	Harpoot and Alexandropol, F
,, 10	1721*b*	20.30±2	F_2	133 E 6 S	Great Kei, F
,, 15	1728	0 48	K_3	99 E. 36 N	
,, 16	1730	7 58	K_3	100 E 25 N	
,, 16	1731	16 34	A_1	140 W 63 N.	
,, 22	1735	9 21?	F_1, M_2	175 E. 12 S	Determined from com. of Christchurch, Sydney, Perth, Honolulu, Manila and Osaka. Multiple earthquake,

Seismic Activity—continued.

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1909		h m.			
Feb. 22	1736	14.14	K_5	37 E 39 N.	Sivas, F.
,, 26	1738	16 42±2	B	95 W. 5 N.	
Mar 5	1748	12.16	K_5	40 E 39 N.	Temran, F.
,, 7	1751	18 5±5	G_1, G_2	50 E. 50 S	
,, 8	1753	11 20	M_2	165 E. 9 S	
,, 10	1755	23 54	E_3	130 E. 29 N	Oshima and Satsuma, F.
,, 11	1756	20 28	E_1, E_2, E_3	140 E 32 N	
,, 12	1757	0 21	E_1, E_2, E_3	140 E. 32 N	
,, 12	1758	23 14	E_1, E_2, E_3	140 E 32 N	From Aomori to Bonin Is, F, and Shimosa, Hitachi, D
,, 13	1760	14 21	E_1, E_2, E_3	140 E 32 N	Awa, Kazusa, D Yokohama and Tokio F.
,, 17	1763	22 53	F_1, F_2	121 E 2 S	Central and North Celebes, D
,, 22	1766	4 23	E_2	146 E 29 N	East coast of Japan, F.
,, 22	1767	20 2	E_2	146 E 29 N	East coast of Japan, F
,, 22	1768	22 3	M_1	168 E 48 S	South New Zealand, F.
,, 27	1769	13 20±3	F_1	152 E 2 S	
April 10	1772	5 23±2	M_2	180 E 9 S	
,, 10	1773	18 43±2		140 E 80 N	Determined from Victoria, Toronto, Indian stations, Osaka and European stations
,, 10	1773*a*	19 36±3	E_1	165 E 45 N	
,, 11	1774	4 2	K_5	45 E 36 N	
,, 11	1775	13 30±3	M_2	175 E 7 S	
,, 12	1777	1 1	M_2	170 E 11 S	
,, 13	1780	22 33	E_3	126 E 13 N	
,, 14	1781	19 53	E_3	125 E 23 N	
,, 23	1785	17 40		9 W 39 N	Benavente and Samora, D
,, 25	1786	1 8	A_1	122 W. 53 N	North Victoria, B C, F
,, 25	1787	21 49	E_2, M_2	140 E 10 N	
,, 25	1788	22 36	F_1, M_2	135 E 6 N	Determined from Manila, Osaka, Sydney, Perth, and Calcutta.
,, 27	1790	12.44±3	F_1	147 E 0 N S	
,, 29	1791	22 34±2	G_1	63 E 27 S	
May 2	1792	6 49±5	M_1	180 E 25 S	Determined from Samoa, Sydney, Perth and Honolulu.
,, 2	1793	18 9±3	F_1, M_2	173 E 10 S	

Seismic Activity—continued.

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1909		h m			
May 10	1801	20 14	G_1	67 E. 8 S	
,, 11	1802	13 0	M_2	179 W 11 S	
,, 12	1805	0 4±2	D_1	84 W. 1 S	
,, 13	1807	14 0±5	H	25 W 30 N	
,, 17	1812	8 3	D_1	65 W 22 S	Topiza, D. Determined from Pilar, Toronto, Honolulu and European stations
,, 17	1812	8 11	K_3	68 E 37 N	Determined from Indian stations, Tiflis and Zikawei
,, 17	1812	8 16	G_1	33 E 35 S	Determined from Capetown, Mauritius and Perth
,, 17	1812	8 21 2	K_6	9 W 41 N.	Determined from max of San Fernando, Azores and Shide.
,, 18	1813	16 44	A_1	132 W 53 N	
,, 18	1814	18 9	A_1	140 W. 51 N.	
,, 23	1823	10 43	E_3	120 E 25 N	
,, 25	1825	4 50	F_1	145 E 0 N S	
,, 26	1826	2 0±3	F_1	145 E 0 N S	
,, 30	1831	6 15	K_5, K_6, K_7	23 E. 39 N	Bolo, D
,, 30	1832	20 57	F_2	131 E 6 S	
June 3	1844	18 44	F_3	102 E 2 S	Korintji, Djambi, D, 200 killed
,, 6	1848	4 50	M_2	147 E 9 N	
,, 8	1851	5 46	D_2	73 W 25 S	Coquimbo, D Taltal, F
,, 9	1852	0 -6	D_2	73 W 25 S	
,, 11	1855	21 6	K_6	5 3 E 43 5 N	St Cannat, D
,, 12	1859	20 20	F_1	170 E 19 S	
,, 22	1893	13 55		10 E 58 N	Determined from British, German stations, Malta, Cairo, Tiflis and Calcutta
,, 22	1893	13 14	E_2	140 E 17 N.	Determined from Osaka, Manila and Honolulu.
,, 27	1910	7 15*ca*	M_2	162 E 10 S	
July 3	1928	19 53 5	K_8	7 E 36 N.	Ain-Trab, Ain-Fakrouna, F.
,, 7	1944	21 34	K_2	71 E 37 N.	A district 8° by 6° shaken
,, 13	1957	13 2	K_1	148 E 62 N.	Determined from Osaka, Manila, Tiflis and British stations
,, 15	1958	0 36	K_5	21 15 E. 37.45 N.	Havari, Kalivia and Sosti, D More than 100 killed and wounded.
,, 26	1980	10.54	G_2	63 E. 8 N.	

Seismic Activity—continued.

Date		No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1909			h. m.			
July	30	1982	10 47	B	101 W. 13 N.	Acapulco and Chilpancingo, D
,,	31	1984	19 18	B	101 W 13 N.	Acapuloo and Chilpancingo, D.
Aug	2	1986	10 14	F_3	95 E 14 N	
,,	7	1999	16 45	M_2	178 W 6 S	
,,	10	2001	6 42	M_2	175 W 15 S.	Tonga, F.
,,	12	2004	11 23	E_3, F_1	126 E 8 N.	
,,	15	2008	6 27	E_3	136 E 36 N.	Central Japan, D.
,,	16	2016	6 58	B	84 W 10 N	San José, Costa Rica, F.
,,	18	2018	0 34	F_1	167 E 14 S	
,,	22	2024	15 40±2	K_3	75 E 37 N	
,,	29	2039	10 28	E_3	128 E 26 N.	
Sept	5	2054*b*	9 10±2	G_1	72 E 16 S.	
,,	7	2058	15 28±2	K_3	70 E 33 N	
,,	8	2059	16 45±5	E_1	180 E 60 N	Two earthquakes ?
,,	8	2060	23 17	F_1	135 E 0 N S.	Doré, D
,,	10	2062	18 7	E_3	26 N 130 E.	Nase, F
,,	10	2063	19 44	E_3	127 E 10 N	E Visayas, F.
,,	11	2065	10 52	E_2	142 E 17 N.	
,,	16	2071	18 49	F_3	102 E 4 S	S Sumatra, F.
,,	16	2072	19 35	E_1	145 E 40 N.	
,,	21	2076	18 49	F_1	132 E 3 N	
,,	23	2078	6 29	F_3	92 E 0 N S	
,,	28	2082	19 57	E_3	122 E 18 N	Aparri, F.
Oct	4	2091	13 39±2	F_1	160 E 12 S	
,,	17	2102	22 12±2	K_2	91 E 41 N	
,,	20	2108	23 42	K_3	68 E 29 N	Quetta and Bellpat, D
,,	27	2114	1 30	M_1	172 E 36 S.	
,,	28	2117	3 53	H	5 W 30 S.	
,,	29	2118	6 45	A_2	124 W 41 N.	Fortuna, N California, D.
,,	29	2119	16.4±1	K_4	31 E 44 N.	
,,	29	2120	17 39±1	K_4	31 E 44 N.	
,,	30	2121	10 13±2	F_1	132 E. 5 S.	N.W. New Guinea to Ambon and Timorlaut, F.
,,	31	2122	10.18	B	105 W. 8 N.	
Nov.	1	2123	6 15±2	H	33 W 0 N S.	
,,	1	2124	9 16	K_3	47 E 36 N.	
,,	3	2126	6 11±5	M_1	145 E 56 S.	
,,	8	2132	20 12	D_2	100 W. 30 S.	Santiago, Copiapo, F.
,,	10	2134	6.12	E_3	132 E. 32 N.	Miyazaki, D. Another earthquake at 135 E. 34 N., Okayama, D.
,,	12	2137	19 48±2	O	30 E 4 S.	
,,	20	2141	12 40±3	E_3	132 E 15 N.	
,,	21	2142	7 36	E_3	122 E 25 N.	
,,	28	2147	0 53±3	M_2	176 W 12 S	
Dec	3	2154	3 2	F_1	145 E 1 S	
,,	8	2159	9 1	F_1	160 E. 7 S.	
,,	9	2160	15.33	F_1	161 E. 8 S.	
,,	9	2161	21.5	F_1	165 E. 10 S.	

Seismic Activity—continued.

Date	No	Time at Origin	District	Lat and Long of Origin	Remarks F=Felt, D=Destructive
1909		h. m.			
Dec. 9	2162	21.42	F_1	127 E. 2 S	Ambon and Piroe, F
„ 9	2163	23.27	E_2, M_2	147 E. 14 N.	
„ 9	2163	23.27	M_2	176 E. 0 N.S.	Determined from Samoa, Honolulu and Sydney.
„ 22	2180	12.38*ca*	F_1	152 E. 3 S.	
„ 23	2182	22.13±3	F_1	160 E. 9 S.	
„ 28	2187	19.17±2	F_1	129 E. 5 S.	

III. *Relation of Amplitude in Seconds of Arc to the Distance of an Origin*

Those who have experienced earthquake movement in the vicinity of an epicentre have many reasons to conclude that it is undulatory in character Earthquake earth-waves have frequently been seen Water in tanks, ponds, and in small vessels has been observed to flow irregularly and intermittently first in one direction and then in another The movement of the fluid suggests that the containing vessel has been subjected to a series of tilts. Pictures and objects free to swing do so in an extremely irregular manner They may move, say, to the right, stop, go further to the right, and again come to rest, after which they may swing suddenly in an opposite direction The hanging lamp or whatever the object may be does not swing freely like a pendulum, but follows a series of irregular displacements of the supporting point

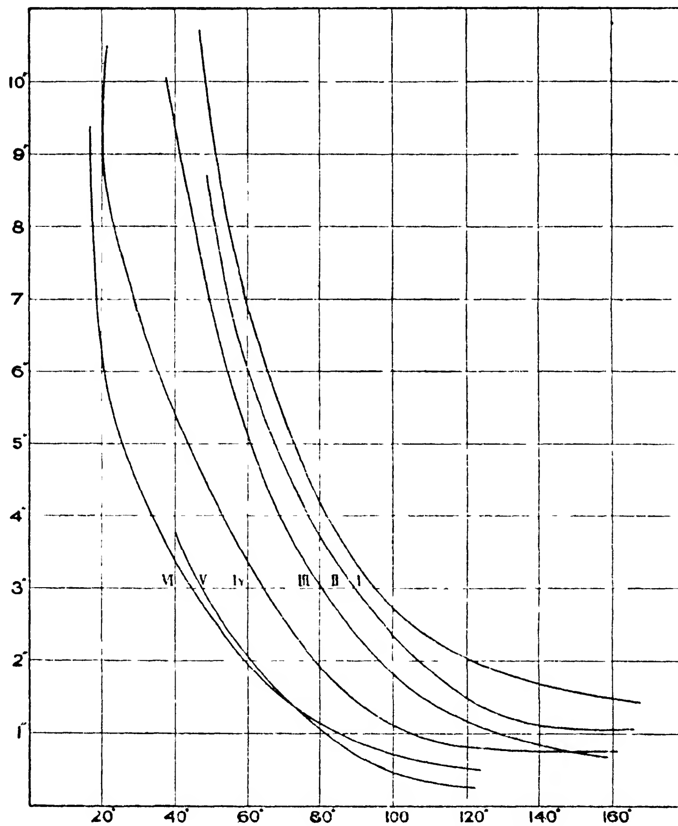
At considerable distances from an origin where the movements are less violent, although they are not so irregular in character, the records from seismographs also give evidence of angular displacements Two similar horizontal pendulums similarly oriented, but adjusted to have different periods, give for the large waves of crypto or teleseismic disturbances records of amplitude the linear measurements of which are very different. The instrument with the longer period yields the larger diagram. If, however, we convert these displacements into angular measure we find that the two records are comparable

In the British Association Report for 1893, p 221, I gave angular measurements for earth-waves which form portions of earthquakes which could be felt. I obtained these records from an ‘ angle measurer or clinometer.’ A similar but much more sensitive apparatus was in 1903 devised by Dr. Schlutter The object was to measure the angular component of teleseismic motion This does not appear to have been detected.

This means that the conclusions arrived at by Dr. Schlutter, which at the present time are shared by several seismologists, are very different from mine

Following my own ideas, in the accompanying diagram I have given curves which show for six large earthquakes the approximate relation between the amplitudes of teleseismic disturbances in angular measure and the distance from an origin measured in geographical

degrees. These measurements are deduced from information published in the British Association circulars, which contain records from the particular kind of instrument they have adopted. The earthquakes



Relation of Amplitude (in seconds of arc) to distance from an origin for six large earthquakes

considered, which I number according to their order in the accompanying diagram, were as follow —

I California, April 18, 1906 observations from 30 stations, 17 good
II Mexico, March 26, 1908 25 observations, 12 good
III Mexico, July 30, 1909 20 observations, 11 good
IV Chile, June 8, 1909 19 observations, 9 good
V Japan, November 10, 1909 22 observations, 11 good
VI Messina, December 28, 1908 23 observations, 12 good

The observations indicated as 'good' fall on or near to the curve to which they refer, the remainder are far removed and erratically placed with regard to the same. The curves as they stand can therefore only be regarded as rough approximations to the truth. They indicate that up to about 80° from an origin amplitude decreases uniformly. From 80° to 120° it decreases less rapidly, and beyond this distance the

decrease is very slow and the curve tends to become asymptotic to the axis representing distance Professor H H. Turner very kindly examined these curves, together with the observations on which they are founded, with the result that two of them were brought more closely in conformity with the remaining four.

At the present time this investigation is, with additional material, receiving careful attention from Professor Turner.

IV. *Direction of Earthquake Motion.*

Between 1881 and 1882, partly in conjunction with the late Professor T Gray, I carried out an extensive series of experiments on earth-vibrations produced by firing dynamite or some other explosive in boreholes of varying depth The resulting movements were recorded by seismographs One result repeatedly shown indicated that the first movement was invariably in the direction of the origin of the explosion [1]

An observation corresponding to this has been shown by Prince Galitzin to accompany teleseismic motion, and when it is pronounced it furnishes the azimuth of the epifocal district To determine whether the *maximum* movements of teleseisms showed any relationship to the direction in which they had been propagated I examined forty-two seismograms of North-South and East-West motion as recorded at Shide In the following table I give the number of a seismogram as entered in the Shide Register, published in the British Association circulars, its date, the latitude and longitude of origin of the disturbance to which it refers, the azimuth of this origin from Shide, and the azimuth as calculated from the North-South and East-West amplitudes Each of these latter may be read as so many degrees east or a similar number degrees west of North.

Register No	Date	Position of Origin	Azimuth of Origin	Azimuth as calculated
	1901			
496	May 25	165 E 12 N	N 20 E	N 30 E
565	Dec 14	121 E 14 N.	N 57 E	N 60 E
571	Dec 31	173 W 41 N	N. 15 W	N. 11 W.
	1903			
705	Apr 29	143 W 43 S	N 55 W	N 54 W.
	1904			
820	Mar 1	178 W 12 S	N 20 W	N 25 W.
838	Apr 12	175 W 44 N.	N. 8 E	N 12 E
847	May 1	130 E 2 N.	N. 22 E	N. 30 E
860	June 25	160 E 53 N	N 11 E	N. 17 E.
863	June 27	160 E 53 N	N 11 E	N. 17 E.
872	July 24	160 E 53 N	N 15 E	N 25 E
877	Aug 8	179 E 42 S	N 5 E.	N. 13 E
884	Aug. 24	135 E 32 N	N. 42 E	N. 47 E.
885	Aug 27	141 W 67 N.	N. 18 W	N. 20 W.
886	Aug. 30	101 E 30 N	N 62 E.	N 57 E.
889	Sept 11	106 E. 23 N	N. 65 E.	N. 65 E
924	Dec 2	132 E. 10 N	N. 55 E	N. 62 E.

[1] See *Phil Trans R S*, part iii, 1882, p 871, *Trans. Seis Soc*, vol viii., 1885, pp 1-82, *Brit Assoc Reports*, 1885, pp. 363, 364.

We have here sixteen instances in which the azimuth of an origin determined from the maxima of North-South and East-West motion approximately agrees with the azimuth as measured on a globe There are, however, in the same interval of time twenty-six instances where no such agreement exists, and this I find to be the case for all the large records obtained during the latter half of 1909. The inference is that the main portion of teleseismic motion, like that of macro-seismic motion, generally takes place in directions independent of the azimuth of its origin

V *On the Relative Duration of Two Rectangular Components of Earth-movement at a given Station*

The records I refer to were made at Shide by a pair of light horizontal Milne pendulums mounted on the same cast-iron frame, and installed upon a brick column One of these recorded N -S motion and the other E -W motion The duration of the movements of the latter practically agreed with the duration recorded by a similar and similarly oriented pendulum on a separate column From this it is inferred that although two light pendulums are carried on one stand they had no sensible effect upon each other's movements I have divided the records into the following four groups, the natural period of the pendulums being different in each group —

Group 1 —May 25, 1901, to January 1, 1902 Period of N -S. boom 19 seconds, and E -W boom 17 seconds Ten large earthquakes had a total duration of 1,341 minutes for N -S movements, and 1,313 for E -W. motion Pendulum with the longest period moved for the longest time, but the difference is very small

Group 2 —February 27 to December 23, 1903 Period of N -S boom 20 seconds, and E -W boom 17 seconds Eleven large earthquakes had a total duration of 730 minutes for N -S motion, and 725 for E -W. motion

Group 3 —January 20 to June 27, 1904 Period of N -S boom 20 seconds, and E -W boom 30 seconds Nine large earthquakes had a total duration of 1,036 minutes for N -S motion, and 1,067 for E -W motion Here again the pendulum with the longest period was disturbed for the greatest length of time

Group 4 —July 24 to October 9, 1904 Period of both pendulums 25 seconds The total duration for eight earthquakes was for N -S motion 725 minutes, and for E -W motion 732 minutes In this instance pendulums with similar periods have been kept in motion for equal intervals of time Nineteen large earthquakes between July 3 and December 10, 1909, show a similar result

From the above notes it might be inferred that the apparent duration of a teleseism largely depends on the sensibility of the recording apparatus to tilting A detailed examination of these records, however, distinctly shows that this is not the case, and that a pendulum with a short period is frequently in movement for a longer interval of time than one with a long period. Amongst the earthquakes referred

to in the above groups I find eight instances in which the direction of the N.-S. motion has exceeded the E.-W. motion by intervals of from 10 to 69 minutes. The azimuths of the origins of these earthquakes were 41, 36, 45, 8, 20, 13, 15, and 5 degrees east of north, which is the direction of Japan or the Central Pacific. In six instances where the E.-W. motion exceeded the N.-S. motion by intervals of from 10 to 46 minutes the azimuths of the origins were 70 E., 79 W., 90 W., 90 W., 69 E., and 12 W., which with the exception of the last suggest origins in Central Asia or Central America. It would therefore appear that marked differences in the duration of two rectangular components of motion are possibly associated with the azimuth of its origin.

VI. *Megaseismic Activity and Periods of Quiescence.*

In the British Association Report, 1910, p. 54, I gave a note on megaseismic activity and rest. The result showed that a large group of megaseisms was followed by a long period of quiescence, while small groups were followed by comparatively short periods of quiescence. This result was based on the examination of twenty-eight groups of large earthquakes. The present discussion is based upon eighty groups, found in the Registers for the years 1899-1908 inclusive. The number of earthquakes in these groups varies from two or three to fifteen. In two cases, however, the number of earthquakes is forty-six and fifty-one. If an earthquake has been recorded over the whole world I have considered its intensity double that of a disturbance which is only recorded over a hemisphere. The intensity of a group is assumed to be the sum of the intensities of each earthquake it contains. Groups usually extend over from one to three days, and it is seldom they extend over more than six days. The intensity per day is the intensity of a group divided by the number of days over which it extended. This quantity does not appear to show any relationship to the number of days of rest which preceded or followed the group which it represents.

The number of days which have elapsed between the centre of one group and the centre of the group which follows has usually been from fifteen to fifty days. In the accompanying figure the number of earthquakes in different groups are plotted in relation to these intervals.

At first sight it would appear that these two quantities had a rough relationship, but it must be remembered that the intervals between centres of groups have frequently been increased by the duration of the groups.

VII. *Megaseismic Frequency in Different Seasons.*

In the Report for 1906 for the seven years 1899-1905 I compared the frequency of large earthquakes in the following three districts:—

1. Districts A, B, C refer to the East Pacific coast north of the Equator, including the Antillean fold.

2. Districts E, F refer to the West and South-west portions of the North Pacific.

3. District K, or the various folds extending from the Balkans to the Himalayas.

The ratios of the numbers of disturbances which were noted in

winter (October 31 to March 31) to those noted in summer in these three districts were respectively 1 to 0·55, 1 to 1·08, and 1 to 1·20

In the following tables these comparisons are continued from the year 1906 to the year 1910 —

Districts		Jan	Feb	Mar	Apl	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
A, B, C	1906	3	1	2	3	0	2	1	1	0	0	0	0	13
	1907	1	0	0	1	0	0	0	1	1	2	0	0	6
	1908	0	1	0	0	1	0	0	0	0	1	1	0	4
	1909	0	0	0	1	2	0	2	1	0	1	0	0	7
	1910	0	1	2	1	2	2	1	1	1	0	0	1	12
	Total	4	3	4	6	5	4	4	4	2	4	1	1	42
E, F	1906	5	3	6	6	2	4	1	3	5	8	6	0	49
	1907	3	1	4	3	8	4	3	4	1	1	3	3	38
	1908	3	1	4	2	3	2	2	1	1	3	8	2	32
	1909	5	5	7	7	7	5	0	6	8	2	3	8	63
	1910	4	3	0	7	11	12	7	3	5	5	4	14	75
	Total	20	13	21	25	31	27	13	17	20	19	14	27	257
K	1906	0	1	2	1	1	0	0	2	0	3	1	1	12
	1907	1	0	1	1	0	0	2	0	1	3	0	1	10
	1908	1	0	3	2	1	1	1	3	1	2	0	3	18
	1909	3	5	2	3	2	1	5	3	1	5	1	0	31
	1910	1	1	0	1	3	5	4	11	3	1	1	2	33
	Total	6	7	8	8	7	7	12	19	6	14	3	7	104

	Earthquakes in Winter	Earthquakes in Summer	Ratio
Districts A, B, C	17	25	1 to 1 47
,, E, F	124	133	1 to 1 07
District K .	45	59	1 to 1 31

These results suggest that the greater number of large earthquakes, whether they originate beneath an ocean or beneath a continent, occur in summer, and a similar result is arrived at if we assume that summer commences on May 1 rather than on April 1

It must, however, be noted that for A, B, C between 1899 and 1905 the greater frequency was found in the winter months With this exception the results here given accord with those obtained previously

If we combine these three districts for the twelve years ending 1910 we find that 365 earthquakes have taken place in the summer and 349 in winter, the winter to the summer ratio therefore being 1 to 1 04.

This close correspondence between winter and summer frequency suggests that megaseismic frequency is but little influenced by epigenic phenomena which follow the six-monthly changes in climate The observation that between 1899 and 1905 the greater frequency was in winter, while subsequently it was in summer, also suggests that megaseismic frequency is not related to our seasons, and if there is a seismic periodicity it must be sought for outside seasonal recurrences

Frequency in the World, 1899 *to* 1909 —In eleven years, or 4,018

the end of seven periods of fifteen months Thus, what would usually be a $7 \times 15 = 105$ months' interval is reduced effectively to 104 The time is reckoned *backwards*, as it seemed best to begin with more modern observations

Initial Date	Total No of Earthquakes	Coefficients of Cos θ	Coefficients of Sin θ	Maximum	Deviation from Mean
June 1909	409	− 9·0	+ 6·4	145°	+195°
Oct 1905	530	+ 7 6	− 3 4	− 24	+26
Feb. 1897	809	+ 5 8	− 6·0	− 48	+ 2
Feb. 1871	779	+ 6 7	− 2 2	− 19	+31
Feb 1845	315	− 3 3	− 7 7	−113	−63
Feb 1819	191	+18 1	−13 1	− 36	+14
Feb. 1793	201	+12 9	− 4 8	− 20	+30
Feb 1767	386	− 7 8	− 4 7	−149	−99
Feb 1689	262	− 8 3	−15 3	−118	−68
Feb 1611	159	+ 2 4	− 1 0	− 23	+37
Feb. 1533	161	+11 5	+ 2 0	+ 10	+60
Feb 1455	78	+ 7 7	−14 4	− 62	−12
Feb 1377	92	+ 5 0	+ 1 1	+ 13	+63
Mean . . .		+ 4·9	− 5 8	− 50	

Each group extends from the initial date given in the first column to the next initial date The first group is thus from June 1909 to October 1905, and contains three periods only. and it is directly discordant This anomaly is under investigation, and for the present we will omit the group The mean formula is then

$$+4\ 9 \cos \theta - 5\ 8 \sin \theta = 7\ 6 \cos (\theta + 50^\circ),$$

the maximum occurring in December 1905, April 1897, &c , two months *later* than the initial date

But a simple harmonic scarcely does justice to the facts If we add together the results for corresponding months for the period of best observations, *i e* , February 1793 to October 1905 (it will be seen how broken is the record in the earlier centuries), and divide by ten so as to get simpler numbers, we get the following sequence, counting the time now forwards in the usual direction

$$\underbrace{22\ 20\ 22}_{64} \qquad \underbrace{21\ 18\ 21}_{60} \qquad \underbrace{18\ 18\ 20}_{56} \qquad \underbrace{17\ 18\ 17}_{52} \qquad \underbrace{19\ 16\ 17}_{52}$$

The starting-point has of course been selected to bring out the main feature, which is an almost steady fall, followed by a very rapid rise when we return to the beginning The idea suggested is that of accumulation. The outward manifestations of stress (earthquakes) fall off in number steadily, but this means that stress is accumulating, and ultimately there is an outburst of numerous earthquakes again If this is the explanation, it may be that the inequality is only quasi-periodic, as in the illustration (quoted first by Dr. Johnstone Stoney) of a pot boiling over and damping the fire, which would tend to recur roughly after a

given interval, but not by any means exactly. The period found can then only be regarded as an average period, and the deviations in the table are intelligible. But it is noteworthy that Mr. Chandler detected a fifteen-month period in the Latitude Variation,[2] though the coefficient is extremely small (only $0''.03$): and some preliminary calculations seem to show that the level error of the Greenwich transit circle also has an inequality of this period. These matters are being further investigated

X. *Intervals in Days from the Commencement of one Group to the Commencement of another*

1899 . . .	47	21	24	21	28	32	25	33	39	41	33				
1900 . .	58	13	27	69	79	40	33	39							
1901 . .	20	38	18	13	19	51	73	32	31	31	28	20			
1902 .	17	28	16	20	21	11	54	24	28	19	30	60	28		
1903	22	11	18	23	26	37	15	20	22	30	19	24	46	43	22
1904 .	13	58	15	15	31	55	29	16	16	15	16	14	17	11	16
	11	17													
1905 .	32	29	19	10	41	15	22	30	24	33	20	48	20	14	6
	7														
1906	37	33	18	18	10	75	21	10	26	29	15	12	14	12	43
1907 . .	15	33	51	18	20	22	30	35	7	28	20	10	41	23	18
1908 .	19	16	32	10	21	7	22	11	93	40	22	20	28	12	
1909 .	15	37	24	16	19	15	15	7	17	19	35	34	7	52	42

A table of the above intervals shows that those of from fifteen to twenty-two days recur no less than fifty-five times, whilst those between eighteen and thirty-three days are repeated twenty-seven times. Intervals of seven, ten, eleven and twenty-four days are each repeated five times, the remaining intervals only occur or recur once, with the exception of the intervals thirty-seven and forty-one days, which recur twice

The inference is that for the world as a whole seismic strain usually finds relief every fifteen or thirty days In other words there is frequently a rough regularity in the recurrence of megaseismic groups

XI.—*Intervals and Days between Successive Megaseisms in Particular Districts*

In the eleven years 1899 to 1909, off the East Coast of Japan to the North of Tokio, I find that thirty-two megaseisms were recorded Twelve of these were separated by intervals lying between fifty-seven and ninety-five days.

To the South of the Philippines round the Celebes and to the West of N.-W. New Guinea during the same period forty-two large earthquakes originated; fifteen of these are separated by intervals which lie between fifty-six and ninety-two days.

XII.—*Geographical Distribution of Megaseisms and Thermometric Gradients.*

For the five years 1899-1903 we have a list of 313 megaseisms, the origins of which are known; of these, sixty-one originated on continental areas, and 252 originated along the lines of troughs or 'deeps,' beneath

[2] *Astr. Journal*, No. 523, p. 152.

oceans. It appears from this that for this particular period there was four times as much seismic activity beneath the cold waters of particular parts of our oceans as there was beneath continental areas. This activity is represented by megaseisms, which usually occur in groups, and the periods of rest which follow the groups are found to be roughly proportional to the intensity of the groups by which they are preceded This suggests that the strain which finds relief in world-shaking disturbances accumulates uniformly, and it may therefore be associated with uniformity in the rate of earth-cooling [3] Should such a relationship exist, it seems likely that sub-oceanic thermometric gradients may be considerably steeper than those which exist beneath continental areas This led me to examine such material as we have at our disposal relating to heat gradients in different parts of the world In 1882, in the Fifteenth Report of the Underground Temperature Committee of the British Association, the late Professor Everett gives a summary of the results of their investigations From a list of thirty-one localities in various parts of the world where observations have been made the conclusion is that the thermometric gradient is on the average 1° F for 64 feet of descent, or 0 000285° C per cm of depth, which, with a rock conductivity of 0 0058, means an average escape of heat annually from each square centimetre of the surface of our world of 41 4 gramme-degrees of heat Sufficient materials to make a complete map of the world, showing the heat gradients, do not exist, but Professor Everett's table may be split into two parts, one of which refers to highlands and the interior of continents and the other to lowlands or localities which are near the sea In the former we find the following seven localities, viz Przibram, in Bohemia, St Gothard Tunnel, Mont Cenis Tunnel, Schemnitz, in Hungary, Manegaon, in India, Yakutsk, in Siberia, and Sperenberg, near Berlin The average gradient for these I find to be 1° F for 75 feet of descent, or 0 000239° C per cm of depth For the remaining twenty-four districts, which are comparatively near to the sea, the average gradient is 1° F for 60 feet of descent, or 0 000303° C per cm of depth With the latter gradient the number of gramme-degrees of heat which escape annually through each square cm of the earth's crust would be 42 4, but with the gradient for the highlands this number becomes 35 5 This means that from the lowlands one-fifth, or 20 per cent , more heat escapes than that which escapes from the inland highlands.

I next turned to the tables of the late Professor Prestwich, published in 1886 [4] In this register I found 329 sets of observations Of these, 283 referred to Great Britain and Ireland, France, Holland, Belgium, Italy, St Petersburg, Algeria, and Buenos Aires These I regarded as countries and places near to the sea Out of this group, 217 have gradients below 1° in 64 feet, which is Professor Everett's average, while the remaining sixty-six have gradients above 64 feet The latter, which are gentle gradients, are to the former, which are steep, in the ratio of 1 to 3 3.

[3] See *Brit Assoc Report*, 1910, p 64
[4] See *Proc. of the Royal Soc.*, vol. xli., 1886.

For Switzerland, Germany, Austria, Central North America, which are distant from the sea, the number of gradients below 1° in 64 feet is 32, while of those above 64 feet the number is twelve In this case the ratio of the gentle gradients to those which are steep is as 1 to 2·6 Here again the inference is that steep gradients increase in frequency as we approach the seaboard In this latter catalogue I find no less than twenty localities where the gradients are 33 feet or less The steepest of this group is at the Dolcoath Mine, in Cornwall, where we have an increase of 1° F for 18 feet of depth For five mines beneath the sea the average gradient is 1° for 38 feet of depth

The only other materials bearing upon this subject with which I am acquainted are lists of heat gradients drawn up by Messrs Koenigsberger and Muhlberg [5] When these are combined with those given by Professors Prestwich and Everett, the following two tables are obtained:

TABLE I.

This gives the average heat gradients in feet per 1° F for inland districts and highlands together with the number of stations at which observations have been made

——	No of Stations	Average Gradient
S E Lancashire, S Yorkshire, Nottinghamshire	9	65
Wales, Inland	2	70
S. Germany, Bohemia, Austria .	12	62
Central France .	6	51
Victoria and New South Wales	2	78
Central United States and Central Canada	13	92 or 79
Witwatersrand, high ground .	1	207
South America, high ground	5	113

The average gradient deduced from these figures is 1° F for 75 feet descent From Everett's tables the estimate was also 1° F in 75 feet.

TABLE II

For low ground, and localities near the sea, the gradients run as follows —

——	Stations	Gradient
Newcastle and Durham District . .	10	52
West Cumberland	2	43
S Wales, near the coast . . .	2	49
Cornwall and Devon .	14	44
Between Glasgow and Edinburgh . .	4	48
N. Germany . .	4	52
West France	4	50
N. France and Belgium . .	8	47
Africa, the Sahara . . .	3	45
N America, E Coast . .	3	59
Mexico, Central . .	2	50

From these figures it would appear that the average gradient of these localities is an increase of 1° F for 52 feet of descent From Everett's tables this becomes 1° F. in 60 feet of descent

[5] See *Trans. Institute Mining Engineers*, vol. 39, 1909-10, p 617

The general result of these examinations indicates that heat gradients beneath high grounds and continental areas are markedly less than those beneath low grounds and the oceans Because seismic activity beneath certain portions of ocean beds is, as I have already said, at least four times greater than it is along shore lines or well inland, and if the gradient beneath continental surfaces is 1° in 75 feet, we might expect a gradient beneath the deeper parts of oceans of about 1 in 19

Another method by which an approximate estimate may be made of suboceanic thermometric gradients is to assume that the steepness of these increases as we descend from a shore line to a sea-bed at the same rate as they increase as we descend from a high level to a shore line In the tables given by Professor Prestwich I find seventeen entries which refer to gradients obtained at elevations lying between 1,017 and 9,529 feet above sea-level Ten of these observations were made at metal mines, six at coal mines, and one in a borehole The mean height of these stations is 2,723 feet The mean of the gradients is 1° F for 68 feet of descent, which, it will be observed, is somewhat less than the average gradient given by Professor Everett The mean gradient from low-lying stations is about 1° F for 60 feet descent The difference between these gradients is therefore 8 feet, and if this difference steadily increases as we descend beneath sea-level, at a depth of 12,000 feet we should expect to find a gradient of 1° F for 25 feet descent This value and the gradient of 1° in 19 feet already suggested, considering what has been observed in mines under the sea, may be rough approximations to thermometric gradients beneath deep oceans With rock conductivity constant, the rate at which heat is lost beneath our ocean would therefore be about three and a half times that at which it escapes from continental surfaces If this is so, we may assume that the suboceanic crust of the world is either thinner or a better conductor of heat than that beneath the land The plumb-line and observations made with pendulums show that high ground and mountain ranges have a deficiency in their gravitational attraction To account for this Sir G B Airy advanced the hypothesis that materials of which they are constituted bulged downwards into a heated denser nucleus beneath This, and the fact that the value of gravity increases as we approach the seaboard, means that the superficial covering of our earth beneath mountains is not only thicker, but it is also less dense than it is beneath lowlands and near the sea

It may also be added that rocks which are heavy and those which are metamorphic or crystalline have a slightly higher conductivity for heat than many other stratified rocks which are comparatively light The crust of our earth beneath a suboceanic depression, partly, perhaps, because it is continually bathed by an oceanic circulation of cold water, is therefore a region where we should expect to find the greatest flow of heat, and consequently it is one where *sudden* contractions which accompany solidification should most frequently occur

Diabase, which is a volcanic rock, when it passes from the fluid to the glassy state contracts about 14 per cent , but at the time of solidification, which takes place at a temperature of about 2,000° F , there is a

sudden contraction of from 3 to 4 per cent.* Beneath an ocean bed with a gradient of 1° F in 20 feet we should expect this to take place at a depth of about eight miles, but beneath a continent with a gradient of 1° in 60 feet at a depth of about twenty-four miles.

XIII. *A Possible Cause of Megaseismic Activity.*

That earth rest after megaseismic activity is roughly proportional to that activity as measured by the number of large earthquakes in a group (p. 24), and that activity in the world is most frequently repeated after fifteen or thirty days of rest (p. 24), suggests that the cause which brings large earthquakes into being which cannot be traced to epigenic influences may be due to the steady dissipation of earth heat. In the first place, this view finds strong support in the fact that the regions where geothermic gradients are steepest are those from which megaseisms most frequently radiate.

Volcanic rock, when passing from the fluid state to the solid, contracts suddenly (see p. 32), and something similar happens when molten slag solidifies. Information bearing on this subject was very kindly obtained for me by Mr. J. J. Shaw, of West Bromwich. To get rid of the slag from an iron furnace it is run into moulds or holders. As it mounts upwards in one of these, its outer edges are seen to contract or curve inwards, leaving a small space between the side of the holder and the hot 'metal.' The hot stream, as it continues to pour, fills up this space. When, however, it has reached a height of one and a half or two inches more in the holder, a second contraction occurs. This intermittent contraction and filling up the space it has left goes on until the holder is full. 'When the block is turned out it shows striæ round its sides which correspond to the intermittent solidifications. Although the conditions of a cooling block of slag are different from those of a cooling globe, they suggest a series of spasmodic contractions at regular intervals rather than a contraction that is uniform,' a phenomenon which is roughly illustrated in the successive sequence of large earthquakes.

When the block cools it frequently cracks, and hot material is exuded. This is due, as pointed out by Mallet, to the grip of the contracting outside shell upon the hot interior.

The huge dykes filled with volcanic rock which traverse many countries, together with the fissure eruptions which have buried many thousands of square miles to depths of from 2,000 to 6,000 feet of lava, correspond, but on a gigantic scale, to the phenomena observed on the surface of the cooling slag.

With each sudden yielding vibrations or waves would be generated on the surface of the viscous mass, and if it is assumed that this is homogeneous, these would be propagated beneath the crust at a uniform velocity, which is the case with the large waves of earthquakes.

The suggestion here made is the reverse of the old idea. It is not a nucleus that contracts to leave a shell to follow downwards, but a

* See *Bulletin of the U.S. Geolog. Survey*, No. 103, 'Igneous Fusion and Ebullition,' by Carl Barus.

forming shell that contracts, which, by its sudden grip on the unshrinking nucleus, fractures itself [7]

XIV *Seismic and Volcanic Activity*

From the 'Catalogue of Destructive Earthquakes' published in the British Association Reports for 1911 a list was constructed which gave the number of earthquakes which had occurred in the year 1800 and each following year up to 1900 A second list, based on information found in 'Die vulkanischen Erscheinungen der Erde,' by Dr Karl Schneider, gave the number of volcanic eruptions in each of these years An inspection of these lists showed that from year to year seismic and volcanic activity seldom remained constant, but rose or fell. When all the entries in the 'Catalogue' were considered it was seen that in forty-nine instances seismic and volcanic activity increased or decreased at the same time, but in the remaining fifty-one years one of these activities became greater whilst the other became less. If only the very large earthquakes having an intensity of II or III were considered, these numbers became respectively 52 and 47

Although we know that a megaseism may shake a dormant volcano into activity,[8] the figures here given suggest that volcanic and seismic activities of the world increase or decrease independently of each other.

A stricter and therefore more satisfactory comparison of these activities may be obtained by reference to the chart which shows the chronological sequence of megaseisms between 1899 and 1910, together with the volcanic eruptions which have been recorded during the same period The number of the latter, with fixed dates, was fifty-eight, and of the former 976 Eruptions and megaseisms have only occurred on the same day seventeen times

XV *On the Mitigation of Air Tremors at Cardiff*

Mr Thomas Chant writes me from Cardiff as follows —

'The air tremors recorded by our seismograph, which have now been reduced, appear to have been caused by movements of the air within the covering case, set up by changes of temperature, and by currents of air moving in the room

'In the first place it was thought that the heat from the small lamp changed the temperature in that part of the case near where it stands To overcome this the lamp is now placed on two strips of asbestos fastened with seccotine to the movable top of the clock box, and two strips of asbestos have been fastened to the ends of the case (bridge) On these latter strips a piece of sheet tin has been fastened. Air now passes under the lamp and between the tin and the end of the bridge, thus preventing the case from becoming warm

'Secondly, movements of air within the case have been partially prevented in the following way · Pieces of thin mica have been fastened to the interior of the case across each end of the bridge, and the boom

[7] See "Bedrock," No 2, 1912
[8] See *Brit Assoc Report*, 1902, p 72, and 1906, p 97.

now passes through two horizontal slits in these pieces of mica. A slit has also been made for the silk thread These narrow strips of mica fixed to narrow cubes of wood, almost making a triangle, rest on the top of the clock box under the movable cover The intention is to reduce the space to which the pendulum swings, and to prevent air movements as far as possible from acting on it

'A small glass slide (microscope cover glass) has been fixed over the slit in the top of the clock box, under the blackened shield at the end of the boom, and a piece of glass fixed to the underside of the movable cover

'Screens made of wood and American cloth have been temporarily placed round the seismograph We intend having a large screen with a cover made to go round and over the instrument, so that the seismograph will be practically enclosed in an American cloth cabinet.

'The pieces of mica and asbestos were used first, and these reduced the tremors When the screens were placed round the seismograph the tremors were further reduced, and when we obtain a new screen I am hoping things will be better still'

Magnetic Observations at Falmouth Observatory—*Report of the Committee, consisting of* SIR W H. PREECE (*Chairman*), DR W. N. SHAW (*Secretary*), PROFESSOR W. G ADAMS, DR CHARLES CHREE, CAPTAIN E W CREAK, MR W. L FOX, DR R T GLAZEBROOK, SIR A W RUCKER, *and* PROFESSOR A SCHUSTER

THE usual number of absolute observations have been made by Mr Kitto The mean values of the magnetic elements for the year 1911 are as follows —

Declination . . .	17° 33′ 0 W.
Inclination .	66° 28′ 2 N
Horizontal force	0 18798 C G S.
Vertical force	0 43172 ,,

These results were deduced from the measurements of the curves made on the five quiet days a month selected by international agreement at de Bilt, the curves being standardised in the usual way by reference to the absolute observations

The measurements of the declination, horizontal force, and vertical force curves on the quiet days were also employed for calculating diurnal inequalities of these three elements and of the inclination which have appeared in the 'Report of the Observatory Committee of the Royal Cornwall Polytechnic Society for the year 1911,' and in the 'British Meteorological and Magnetic Year Book,' Part IV (2), published by the Meteorological Office

A new suspension was fitted to the horizontal force magnetograph by Mr E Gold in July 1911, and for a few days thereafter the drift of zero in the instrument was too large to admit of satisfactory measurement of the curves Under the circumstances it was decided to omit

two of the quiet days selected for July at de Bilt, basing the inequality on the remaining three

The magnetic character of individual days has been decided by Mr. Kitto as in previous years, and communicated to Professor van Everdingen at de Bilt for inclusion in the International List

Having received an intimation that the contributions from the British Association and Royal Society would be discontinued, the following letter was circulated to those interested in the work of the Observatory:—

The Observatory, Falmouth,
December 9, 1911.

FALMOUTH METEOROLOGICAL AND MAGNETICAL OBSERVATORY

DEAR SIR,—The work of the Falmouth Observatory was originally undertaken at the request of the Meteorological Committee of the Royal Society, and it was placed under the local care of the Royal Cornwall Polytechnic Society Under a Special Committee of that body the work has been carried on without intermission since March 1868, an annual grant being contributed for that purpose by the Meteorological Office

At the close of 1883 negotiations were entered into with the Meteorological Office which resulted in the Royal Cornwall Polytechnic Society providing a new site and erecting buildings for observatory purposes The new observatory was opened in 1885

At the instance of several prominent members of the Royal Society opportunity was taken at this juncture to initiate the recording of the terrestrial magnetic elements A chamber was provided in the basement of the new building for this purpose, and a set of self-recording magnetographs was placed there by the Royal Society, who also provided the necessary instruments for absolute magnetic observation Regular magnetic records commenced in January 1887, and from that date the meteorological and magnetic work has been continued without intermission

In 1901 the Royal Cornwall Polytechnic Society gave notice that they were unable to continue the magnetic work without pecuniary aid, and that it would cease if the aid were not forthcoming

From that date grants were given by the Royal Society and the British Association

In view of matters connected both with the finances and the personnel of the Observatory, this Committee do not see their way to continue the observations after the close of 1912, and feel it only due to the scientific authorities who have so long and so consistently supported the Falmouth Observatory that they should be at once apprised of the fact —Your obedient servant,

WILSON L FOX,
Honorary Secretary, Observatory Committee of the
Royal Cornwall Polytechnic Society

The Director, Meteorological Office

FALMOUTH METEOROLOGICAL AND MAGNETICAL OBSERVATORY

The Committee of the Falmouth Observatory respectfully submit the following, amongst other reasons, why it appears to them that upon scientific grounds the Falmouth Observatory should be continued In the Report of the Grant Administration Committee of the British Association, consisting of Sir W H Preece (chairman), Dr W N. Shaw (secretary), Dr. W G. Adams, Captain Creak, Mr Wilson L Fox, Dr. R T Glazebrook, Professor A Schuster, Sir A W Rucker, and Dr. Charles Chree, allusion is made to several of these points

As regards Meteorology

1 The situation at the extreme South-West of England and the opening of the Channel is one of exceptional meteorological importance.

2 The Observatory serves the purpose of a central station of reference for meteorological data for the South-West of England

3 Continuous records of pressure, temperature, wind, rain, &c, must still be the foundation of future progress in meteorology, and the existence of records over the long period of forty-three years is in itself a ground for their permanent maintenance

As regards Magnetic Work

4 The conjunction of Falmouth with Eskdalemuir for the effective representation of the details of the variation of terrestrial magnetic force

5 On account of the difference in latitude, the character of the disturbances recorded at the new Observatory at Eskdalemuir is more different than that at Falmouth from the accepted standards of Kew Observatory, therefore, owing to the similarity of latitude, the Falmouth records will be suitable in comparison with those at Kew Observatory for the investigation of secular change

6 The position of Falmouth is exceptionally favourable from the magnetic point of view, because it is on the coast in close proximity to the Atlantic Ocean, and therefore affords special facilities for making a connection between the land magnetic surveys and the ocean survey This has been demonstrated by the visit of the 'Carnegie,' the magnetic-survey ship of the Carnegie Institution of Washington, which for the purpose of such connection made Falmouth its first port of call

7 The problems of terrestrial magnetism, to the solution of which the observatory has contributed its records during the past twenty-four years, are still engaging the joint investigation of eminent physicists throughout the world In this connection special data are frequently sought from and furnished by the Falmouth Observatory

8 Long before the Kew Observatory was affected by electric trams the Royal Society felt the importance of supporting the establishment of an additional observatory at Falmouth, by contributing the instruments necessary for continuous photographic records, and for absolute observations

9 The scientific value of and necessity for continuity of observations

The Committee desire to express their regret that the difficulties in the way of continuing the magnetic observations which were begun in 1887 have not been overcome

The Committee hope that, with a view to assisting the appeal for a Treasury Grant for the Falmouth Observatory, a resolution may be passed by Section A recommending that in the interests of science Falmouth Observatory may be efficiently maintained

---

Investigation of the Upper Atmosphere, in co-operation with a Committee of the Royal Meteorological Society —Eleventh Report of the Committee, consisting of Dr W. N SHAW (*Chairman*), Mr. E GOLD (*Secretary*), Messrs D ARCHIBALD, C. VERNON BOYS, C. J. P. CAVE, *and* W H DINES, Dr. R T. GLAZEBROOK, Sir JOSEPH LARMOR, Professor J. E PETAVEL, Dr. A SCHUSTER, *and* Dr W WATSON.

MEETINGS of the Joint Committee were held in the rooms of the Royal Meteorological Society on October 18, 1911, and July 5, 1912 At the meeting in October it was decided to continue the ascents of registering balloons at Mungret College, Limerick, with the co-opera-

TABLE I.—*Summary of Registering Balloon Ascents at Limerick, September* 1911 *to June* 1912.

Date	Time	Maximum Height	Place of Fall: Distance	Place of Fall: Direction	Hc	Tc	Gradient Velocity	Gradient Direction	Approximate Pressure at Sea Level in Millimetres	Character of Curvature of Isobars (a=anticyclonic, c=cyclonic, s=straight)
1911		km	km.	°	km	km	m p s.	°		
September 11	6 43 p m	*	620	**56**	—	—	3	**80**	762	a
,, 12	7 0 a m	14	90	**30**	1st race 10 7 2nd ,, 11 0	217 219	6	**70**	762	a
,, 12	6 50 p m	15	60	**45**	11 2	216 5	5	**45**	763	a
,, 13	7 0 a m.	18	48	**70**	10 4	222	10	**350**	765	a
,, 15	7 20 p m.	16	38	**180**	9 9	221	4	**50**	772	a
November 7	7 10 a m	14 2	54	**142**	7 8	220	13	**245**	756	s
1912										
June 6	7.0 a m.	13 6	23	**190**	9 2	221	9	**10**	756	c

* Maximum height certainly did not exceed 6 km , but radiation spoilt the record above 5 km.

Ascents in which Balloons were not recovered.

1911—December 6, 7 a.m. ,, ,, 7, 7 a m.	1911—December 8, 7 a m	1912—January 3, 7 7 a m ,, ,, 4, 7 10 a m	1912—April 11, 7 a.m ,, ,, 12, 7 a.m.

TABLE II.—*Temperature Recorded in Registering Balloon Ascents made at Limerick from September 1911 to June 1912 inclusive.*

Height km	Sept 11, 1911 6 43 P M Pressure mgd	Sept 11, 1911 Temp °A	Sept 12 1911, 7 A M Pressure mgd	Sept 12 1911, 7 A M Temp °A	Sept 12 1911, 7 A M Temp °A	Sept 12, 1911, 6 50 P M Pressure mgd	Sept 12, 1911, 6 50 P M Temp °A	Sept 13 1911 7 A M Pressure mgd	Sept 13 1911 7 A M Temp °A	Sept 15, 1911, 7 20 P M Pressure mgd	Sept 15, 1911, 7 20 P M Temp °A	Sept 15, 1911, 7 20 P M Temp °A	November 7, 1911, 7 10 A M Pressure mgd	November 7, 1911, 7 10 A M Temp °A	November 7, 1911, 7 10 A M Temp °A	June 6, 1912, 7 A M Pressure mgd	June 6, 1912, 7 A M Temp °A	Height km
Ground	1 011	289	1 012	284		1 012	284 5	1 013	283	1 025	282		0 998	279 5		1 005	285	Ground
0 5	0 952	283	0 958	283	281	0 955	283	0 956	281	0 968	278 5		0 940	278		0 950	281	0 5
1 0	0 898	280	0 901	281 5	279 5	0 898	278	0 898	277	0 910	274		0 884	274 5		0 892	278	1·0
1 5	0 848	277	0 848	279	277	0 845	277	0 845	273	0 853	270		0 831	270·5		0 840	275	1 5
2·0	0 798	275	0 796	276	274	0 796	275 5	0 796	277	0 802	272		0 781	268	266	0 791	271	2·0
2 5	0 750	272	0 750	274	273	0 750	273 5	0 750	273 5	0 752	270		0 733	265	262	0 741	266	2 5
3 0	0 702	269 5	0 704	272	271	0 704	271	0 702	270·5	0 705	268		0 688	261	259	0 694	267	3·0
3 5	0 660	268	0 661	269	268	0 661	268	0 660	267·5	0 662	264·5		0 644	256	255	0 651	265	3 5
4·0	0 618	265	0 621	266	265	0 620	265	0 618	265	0 621	261		0 603	251·5		0 611	262	4 0
4 5	0 581	262	0 582	263·5	261 5	0 582	262	0 581	262·5	0 581	257		0 565	248		0 572	258	4 5
5·0	0 542	?259	0 547	260·5	259	0 544	259	0 544	259	0 542	253		0 527	243		0 534	253	5·0
6	—	—	0 480	253 5	252·5	0 478	253	0 478	255·5	0 474	246		0 457	234		0 465	245	6
7	—	—	0 418	248	247	0 417	246	0 417	243·5	0 411	239	238	0 395	226		0 405	235	7
8	—	—	0 367	241	239	0 364	238	0 361	236	0 355	233	231	0 340	221		0 351	228	8
9	—	—	0 318	233	230·5	0 316	232	0 315	231	0 304	224 5		0 291	223		0 301	222	9
10	—	—	0 275	224	221	0 274	224	0 272	224	0 262	221		0 251	223		0 258	223	10
11	—	—	0 235	219		0 235	217	0 245	223	0 224	221		0 217	226		0 222	226	11
12	—	—	0 203	223	221	0 201	220	0 201	224	0 192	221		0 187	226		0 191	?	12
13	—	—	0 175	224	222	0 172	220	0 171	222·5	0 164	221		0 161	222		0 164	?	13
14	—	—	0 150	226		0 150	220·5	0 148	223	0 142	220		0 137	220		—	—	14
15	—	—	—	—		0 127	221	0 127	223	0 121	219·5		—	—		—	—	15
16	—	—	—	—		—	—	0 110	223	0 104	219		—	—		—	—	16
17	—	—	—	—		—	—	0 094	223·5	—	—		—	—		—	—	17
18	—	—	—	—		—	—	0 081	224	—	—		—	—		—	—	18

tion of the Rev. W. O'Leary, S J , so far as the funds at the disposal of the Committee would permit

As the cost of hiring cylinders for hydrogen for the ascents was considerable, it was subsequently decided to purchase a cylinder, and accordingly an 80-foot cylinder and cover were obtained from the British Oxygen Co , Glasgow This, at a cost of 3*l* 3*s*. 9*d* , holds sufficient hydrogen for the single and short series ascents, but an additional cylinder is necessary for the long series of ascents extending over a week

Ascents have been made in September, November, December 1911, and January, April, June 1912. No ascents were made in March and May owing to unfavourable weather conditions The ascent could not be made in February through the delay in getting hydrogen owing to the dock strike at Glasgow

Particulars of the ascents, including the date and time, the height reached, and the conditions of the pressure distribution at the time are given in Table I. The detailed values of the temperature at different heights are given in Table II

Out of the fourteen balloons liberated seven have been recovered, giving six good records to heights of 13 to 18 kilometres In all six cases the stratosphere was reached Out of eighteen balloons liberated since ascents were begun at Mungret College in June 1911, ten have been recovered, giving nine records to heights varying from 13 to 21 kilometres The average height of the stratosphere from these ascents is 10 7 kilometres, which is very nearly the same as the mean height for England The majority of the ascents relate, however, to the summer and autumn months, when the mean height is greater than usual The pressure was also above the average at the time of the ascents, the mean for the nine occasions being approximately 764 mm for M S L Thus, so far as these ascents give information as to the average state of affairs, the results indicate that the stratosphere is lower over Ireland in the summer and autumn months than it is over England or the Continent

It ought, however, to be pointed out that the ascents were made for the most part during a period when there was a gradient for northerly winds, and it is under such conditions that low values of Hc appear to occur in other places

Three ascents made in Ireland, in July 1908 and August 1910, by Captain Ley, gave a higher value for the mean height, 11 7 kilometres, corresponding with a mean sea-level pressure of 767 mm If account is taken of the pressure and of the season the value is, however, not greater than the mean value for England or the Continent. (The value of Hc increases by about 0 5 kilometre for each 4 mm increase of pressure)

None of the seven balloons sent up in December 1911, January and April 1912, were recovered, but as only one balloon was recovered out of eight sent up by Mr Dines at Pyrton Hill in the same period, it is probable that the losses are to be attributed to the special character of the weather rather than to the situation of the station

The results obtained are indeed very gratifying, and the best thanks

of the Committee are due to the Rev W O'Leary and the authorities of Mungret College for their assistance, without which such a series of ascents would have been quite beyond the resources at the disposal of the Committee

The Joint Committee have arranged to continue ascents at Mungret College, but they have decided that investigations over the sea are necessary both to supplement this work and to solve the problem of the effect of the ocean on the height of the stratosphere, and to throw further light on the connection between the distribution of pressure and the vertical temperature gradient

There is, moreover, a better chance of recovering balloons at sea than on land in clear weather, since a vessel of moderate speed can keep the balloon in sight for a sufficient time to give a good indication of the place of fall

The Committee therefore ask for reappointment with a grant of 50*l*, to be devoted to balloon ascents over the sea.

Experiments for improving the Construction of Practical Standards for Electrical Measurements.—Report of the Committee, consisting of Lord RAYLEIGH (*Chairman*), Dr R T GLAZEBROOK (*Secretary*), Professors J. PERRY, W G. ADAMS, *and* G CAREY FOSTER, Sir OLIVER LODGE, Dr A MUIRHEAD, Sir W. H PREECE, Professors A SCHUSTER, J A FLEMING, *and* Sir J. J THOMSON, Dr W. N SHAW, Dr J T BOTTOMLEY, Rev T C FITZPATRICK, Professor S P THOMPSON, Mr. J. RENNIE, Principal E H GRIFFITHS, Sir ARTHUR RUCKER, Professor H L CALLENDAR, *and* Messrs G MATTHEY, T MATHER, *and* F E SMITH

IT was understood at the last meeting of the Committee that when the republication of the Reports was complete the Committee would not ask for reappointment The Reports from 1861 to 1911 inclusive have now passed through the press, and it is intended that this, the 1912 and final Report of the Committee, should conclude the reprints, which will be on sale in the autumn of the present year

It seems desirable, however, that the Committee should remain in existence until all questions connected with the republication are determined, and accordingly they ask for reappointment

With regard to absolute measurements we have, as the direct result of the work of members of the Committee, two pieces of apparatus which should prove equal to any demand for precise measurements in the absolute system for very many years

A report of the British Association Ayrton-Jones current balance appeared in 1908, and it was stated at that time that the probable error associated with a determination of current in absolute measure was about two parts in 100,000 Since then the balance has been used on several occasions, it continues to give satisfaction, and there appears to be no reason for doubt that so far as the absolute measurement of current

is concerned an accuracy within at least five parts in 100,000 can still be guaranteed. This conclusion is greatly strengthened by the results which were communicated to the Association last year by Dr Dorsey of the Bureau of Standards, Washington At that institution Drs. Rosa and Dorsey have made experiments with a new current balance, the coils of which are arranged in a manner similar to those used by Joule and by Lord Rayleigh They obtained results for the electromotive force of the Weston normal cell which agree with those obtained at the National Physical Laboratory within four parts in 100,000 Whether this represents a real difference in the results given by the two balances, or is an actual difference in the E M F 's of the reference cells used, has not yet been decided

With regard to the absolute measurement of current elsewhere, a current weigher has been built at the Laboratoire Central d'Électricité, Paris, and at the Reichsanstalt further measurements are to be made in the near future It will be seen therefore that the absolute measurement of current is on a very satisfactory basis At the National Physical Laboratory no efforts will be spared to maintain the Ayrton-Jones balance in good condition and to obtain results equal in precision to those obtained at the present time

Turning now to the absolute measurement of resistance For many years no measurements of this quantity have been carried out, but at the present time the Lorenz apparatus at the National Physical Laboratory and other apparatus now being constructed at Berlin and Washington will place measurements of resistance in a position equally satisfactory with those of current The Lorenz apparatus is now being employed for the measurement of resistance, and it is believed that the probable error will not exceed two parts in 100,000 This satisfactory state of affairs is largely due to the design and size of the apparatus and the ease with which the dimensions of the coils can be measured Many years ago Lord Rayleigh showed that it was not necessary to measure accurately the diameter of the coils of a Joule balance, the ratio of the diameters was sufficient, and this ratio could at any time be obtained by measuring the ratio of two currents In consequence, with a Joule balance an observer is not handicapped in his measurements by the results of linear observations which may have been made many years previously and which may be incorrect owing to secular change With the Lorenz apparatus independence of previous linear measurements has been secured by winding the coils with bare copper wire and leaving them in this condition This enables linear measurements to be made at any time with ease and with precision.

Referring now to material standards, it is most gratifying to record that measurements of resistance, of current, and of electromotive force are now made on the same basis in practically all civilised countries This satisfactory state has been achieved within the past four years and is a direct result of the labours of the London Conference of 1908, in which this Committee was so largely interested

As is well known, the International standard of resistance is that of a specified column of mercury, and that of current depends on measurements with the silver voltameter. The measurement of electro-

motive force and of current may be conveniently made by means of the Weston normal cell.

During the past two years comparisons of resistance coils and of standard cells, and comparative experiments with the silver voltameter, have been made by representatives of the National Physical Laboratory and the standardising laboratories of America, France, and Germany. The results obtained show better than any formal statement the remarkable agreement which now exists between the electrical standards of the four countries named

Table I gives the results of measurements made at the Bureau of Standards, the Reichsanstalt, and the National Physical Laboratory, on four hermetically sealed resistance coils of manganin The values given are in international ohms at 25° C

TABLE I.

No of Resistance Coil	B S March 1911	N P L April 1911	P T R June 1911	P T R Dec 1911	N P L Dec 1911	B S Jan 1912	B S June 1912	Maximum Difference
11	$1\,00005_3$	$1\,00005_2$	$1\,00004_2$	$1\,00003_7$	$1\,00005_0$	$1\,00005_3$	$1\,00004_9$	$0\,00001_6$
12	$1\,00005_5$	$1\,00005_3$	$1\,00004_3$	$1\,00003_8$	$1\,00005_1$	$1\,00005_4$	$1\,00005_1$	$0\,00001_7$
3939	$1\,00009_9$	$1\,00010_0$	$1\,00008_7$	$1\,00008_3$	$1\,00010_0$	$1\,00009_3$	$1\,00010_0$	$0\,00001_7$
3940	$1\,00009_8$	$1\,00010_0$	$1\,00008_8$	$1\,00008_5$	$1\,00010_0$	$1\,00009_9$	$1\,00010_1$	$0\,00001_6$

Table II gives the results of measurements of the E M F of the Weston normal cell The measurements were made at Washington by representatives of the Bureau of Standards, the Reichsanstalt, the Laboratoire Central d'Électricité, and the National Physical Laboratory The current was measured by means of silver voltameters of various types and capacities, and the electrolytes were from various sources In the opinion of some of the experimenters certain forms of the voltameters were untrustworthy and some of the electrolytes were known to be impure The agreement of the various means, while being very

TABLE II

Date, 1910	Number of Voltameters in Circuit	Calculated E M F of Weston Normal Cell at 20° C	Difference from Mean 1×10
April 14	4	1 01825	−6
„ 15	8	33	−2
„ 18	4	27	−4
„ 20	8	31	0
„ 22	4	29	−2
„ 26	8	37	+6
„ 28	4	32	+1
„ 30	5	34	+3
May 2	7	37	+6
„ 3	5	36	+5
„ 5	8	35	+4
„ 7	8	28	−3
„ 12	6	30	−1
„ 19	4	26	−5

Mean=1 01831.

TABLE III.—*Results at Washington with N.P.L. Non-septum Voltameter.*

Date, 1910	Calculated E M F of Weston Normal Cell at 20° C	Difference from Mean 1×10^{-5}
April 15	1 01831	+2
„ 15	28	−1
„ 20	31	+2
„ 20	28	−1
„ 30	31	+2
May 2	27	−2
„ 5	28	−1
„ 12	25	−4

Mean = 1·01829.

satisfactory, is not therefore a true indication of the reproducibility of the silver voltameter To give an idea of this reproducibility the results obtained at Washington with a non-septum form of voltameter, designed at the National Physical Laboratory, are given in Table III The results of one experiment only have been omitted and in that the current was unusually unsteady

Table IV gives the results of measurements on a number of Weston normal cells The values given are the differences in microvolts between the E M F 's of the cells and the reference standards of the various laboratories

TABLE IV —*Differences in Microvolts.*

Stand Cell No	B S June and July 1911	N P L Aug 1911	P T R Sept and Oct 1911	N P L Oct 1911	L C E Oct 1911	N P L Nov and Dec 1911	B S Jan 1912
262	− 6	—	− 70	—	−80	−60	—
267	41	—	0	—	—	—	—
268	37	—	− 15	—	—	—	—
51	−58	—	− 70	—	− 30	—	—
32	−69	—	−115	—	−130	—	—
301	−24	− 5	− 30	—	− 15	—	−40
304	19	23	0	—	0	—	7
309	−36	−27	− 45	—	− 20	—	−56
310	0	− 4	− 25	—	− 10	—	−44
A1	−13	−12	− 15	—	− 10	—	−22
43	2	3	− 30	—	5	—	0
44	0	—	− 15	− 7	—	—	− 1
19	−27	—	− 45	−30	—	—	−28
22	−31	—	− 40	−29	—	—	−30
238	− 2	—	20	52	—	—	−10
350	−24	—	− 20	1	—	—	−24
352	−31	—	− 45	−30	—	—	−30
133	—	—	—	—	30	—	34
142	—	—	—	—	30	—	33
1 3	—	—	—	—	—	− 6	− 5
1 33	—	—	—	—	—	−16	−16
17	—	—	—	—	—	− 5	− 8

The Committee feel that these results are sufficient to show that the primary objects for which they were appointed have been achieved, and

that the present position of electrical standards—as outlined in this Report—is very satisfactory.

With a view to completing the business arrangements connected with the republication, the Committee recommend that they be reappointed, that Lord Rayleigh be Chairman and Dr. R T Glazebrook Secretary.

Establishing a Solar Observatory in Australia.—Report of the Committee, consisting of Sir DAVID GILL (*Chairman*), Dr. W. G DUFFIELD (*Secretary*), Rev. A. L CORTIE, Dr W. J. S LOCKYER, Mr. F McCLEAN, *and* Professors A SCHUSTER *and* H. H TURNER, *appointed to aid the work of Establishing a Solar Observatory in Australia.*

THE following report has been received from Dr Duffield relating to the progress of the movement to establish a solar observatory in Australia —

'The Commonwealth Government of Australia has been pleased to accept the following apparatus, which, through the generosity of the gentlemen named below, I was enabled to offer in 1909 towards the equipment of a solar observatory

'1 A 9-inch Grubb refractor	The gift of Mr James Oddie, of Ballarat, Victoria
'2 A 26-inch reflecting telescope	
'3 An 8-inch reflecting telescope	
'4 Electrical equipment	

'5 A 6-inch Grubb refractor, the gift of the trustees of the estate of the late Lord Farnham (Sir Howard Grubb, F R S , and the late Mr W E Wilson, F R S)

'The Commonwealth Government has already taken delivery of the Oddie gift, and I have been authorised by the Commonwealth to spend £100 upon the Farnham telescope and to forward it to Australia

'In view of this action by the Government there can be no doubt of their intentions in the matter of solar work

'I have consequently recently offered to the Government without further guarantee the following equipment for solar work —

'6 A spectroheliograph, 7 A Littrow spectrograph, 8 A pyrheliometer

'In addition to these there will be attached to the Farnham telescope:—

'9 An Evershed prominence spectroscope

'These offers are rendered possible by the generosity of gentlemen who either have at heart the progress of solar physics or the prestige of Australian science '

The following report over the signature of the Commonwealth Statistician concerning the choice of site will be read with interest:—

'In January 1910 the Commonwealth Government appointed a Board consisting of R A. Macdonald (Under-Secretary for Lands, N S.W.), R. P. Sellors (Geodetic Survey, N.S.W.), C. R Scrivener

(Commonwealth Director of Surveys), H A Hunt (Commonwealth Meteorologist), P Baracchi (Government Astronomer, Victoria) to inquire and report upon the best site for an observatory within the Federal Territory at Yass-Canberra The Board unanimously selected and recommended a site on the summit of a hill some 2,500 feet above sea level, which, in their opinion, was probably as suitable for the purpose as any place in Australia

'The Commonwealth Government, having accepted the recommendations of this board, instructed Mr Barracchi to establish a temporary observatory at the selected site, and, from an astronomical point of view, to test the locality in order to determine definitely whether it answered the requirements of modern scientific research, including astrophysics The Department of Home Affairs has prepared plans for a dome to house a 9-inch refracting telescope, and the work is now actually proceeding The telescope is the gift of James Oddie, Esq, of Ballarat, who offered it, together with other instruments and appliances, on condition that it would be utilised as a part of the equipment of a solar observatory It is proposed to erect at the site this 9-inch refractor, upon which a Dallmeyer photographic lens, 6-inch aperture and 42-inch focal length, is now being mounted, and for a year to make observations during one week in every six weeks, the observations to be carried out alternatively by Mr Barracchi and his chief assistant, Mr J M Baldwin '

Mr Barracchi in a letter to the Rev A L Cortie thus describes his observations —

'The little observatory at Yass Camberra consists of a 20-feet dome resting on walls of concrete, with four little wings, kitchen, two bedrooms, and a photographic room The instruments are the 9-inch refractor by Grubb (which was presented to the Commonwealth Government by Oddie of Ballarat), a chronograph and a clock We have mounted on this telescope a 6-inch doublet (Dallmeyer), focus 38 inches, which gives us a first-rate field of 10 degrees in diameter, and I have got splendid photographs of rich star fields We have also a good and convenient transit hut and a 3½-inch transit instrument mounted on a solid masonry pier, and that is all for the present Baldwin and I go there once a month alternately, and stay there a week We find the atmospheric conditions remarkably good We have never got less than four fine days and nights out of seven In clear weather the sky is deep blue even in the immediate vicinity of the sun, and the definition is good at as low an altitude as 10 degrees The night skies are simply magnificently brilliant After our Melbourne sky, the sight of the heavens at Mt Strom is surprisingly beautiful Mt Strom is the official name of the hill upon which the observatory stands It is 2,500 feet above sea level, and about 500 feet above the general level of the surrounding country I intend to carry on observations of the sun and take star photographs as well as other star observations for testing atmospheric conditions and definition for a complete year, after which I will report to the Government as to the suitability of the locality for a great modern observatory, more particularly solar '

The Study of Plant Enzymes, particularly with relation to Oxidation.—*Report of the Committee, consisting of* Mr. A. D. HALL (*Chairman*), Dr. E. F. ARMSTRONG (*Secretary*), Professor H. E. ARMSTRONG, Professor F. KEEBLE, *and* Dr. E. J. RUSSELL.

THE Committee have made considerable progress in the investigations which they have undertaken. The following is a list of communications by members of the Committee submitted to the Royal Society and published during the past year:—

(*a*) 'Herbage Studies,' I. '*Lotus corniculatus*, a cyanophoric plant,' by H. E. Armstrong, E. F. Armstrong, and E. Horton.

(*b*) 'Studies on Enzyme Action.' XV. 'Urease, a Selective Enzyme,' by H. E. Armstrong and E. Horton.

(*c*) 'The Distribution of Oxydases in the Plant and their rôle in the Formation of Pigment,' by F. Keeble and E. F. Armstrong.

(*d*) 'Studies on Enzyme Action.' XVI. 'The Enzymes of Emulsin, (i) Prunase, the correlate of prunasin,' by H. E. Armstrong, E. F. Armstrong, and E. Horton.

(*e*) 'Studies on Enzyme Action.' XVII. 'Enzymes of the Emulsin type, (ii) The distribution of β-enzymes in plants,' by H. E. Armstrong, E. F. Armstrong, and E. Horton.

(*f*) 'Studies on Enzyme Action.' XVIII. 'Enzymes of the Emulsin type, (iii) Linase, and other enzymes in *Linaceæ*,' by H. E. Armstrong and J. V. Eyre.

(*g*) 'The Oxydases of *Cytisus Adami*,' by F. Keeble and E. F. Armstrong.

Much preliminary work has been done in directions other than those considered in these communications, particularly with the object of throwing further light on the nature of the oxydases, the manner in which they act and the part they play. The subject is one of great complexity and difficulty, and it is clear that it will be necessary to extend and multiply observations and experiments in a variety of fields if definite conclusions are to be arrived at. It is impossible to study the already voluminous literature of the subject and not be struck by the absence of proof that the oxydases are selective agents comparable with enzymes; at most it has been shown that their activity is of a catalytic order and usually limited, a particular oxydase apparently exercising its effect only within a certain group of compounds.

The Committee ask to be reappointed with a grant of 30*l*.

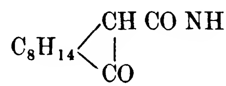
Dynamic Isomerism.—*Report of the Committee, consisting of* Professor H. E. ARMSTRONG (*Chairman*), Dr. T. M. LOWRY (*Secretary*), Professor SYDNEY YOUNG, Dr. C. H. DESCH, Dr. J. J. DOBBIE, Dr. M. O. FORSTER, *and* Dr. A. LAPWORTH. (*Drawn up by the Secretary.*)

Camphorcarboxamide and Camphorcarboxypiperidide.—During the past year an investigation has been completed of the isomeric changes taking

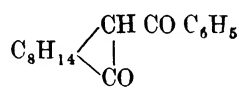
place in solutions of two crystalline derivatives of camphorcarboxylic acid (the amide and piperidide), which were first prepared and examined about four years ago by Dr. Glover. The changes of rotatory power which take place in the freshly prepared solutions are extremely complex. In solutions of the piperidide in benzene, a period of induction is followed by two periods of acceleration and two periods of retardation in the rate of change of rotatory power, the changes can only be explained by assuming that three distinct isomeric changes take place, and that a condition of equilibrium is ultimately established between four distinct isomerides

Measurements of solubility have shown that in the case of each substance a proportion amounting to about one-third persists in the original form when a condition of equilibrium is finally attained to

In purifying the two substances it was found to be almost impossible to secure homogeneous material until they were separated in the form of measurable crystals from solutions in ethylic acetate A remarkable morphotropic relationship was detected between the amide



and a-benzoyl camphor



An investigation of the equations for two consecutive unimolecular changes has already been published,[1] and a detailed account of the experiments referred to above will be published at an early date

The Committee ask for reappointment and for a grant of 30*l* as in the preceding year

---

The Transformation of Aromatic Nitroamines and Allied Substances, and its Relation to Substitution in Benzene Derivatives —Report of the Committee, consisting of Professor F S Kipping (*Chairman*), Professor K J P Orton (*Secretary*), Dr S Ruhemann, *and* Dr J T Hewitt.

I *The Conversion of Chloro-, Bromo- and Nitro-aminobenzenes into Substituted Anilines*

In the recent reports of this Committee, the results of work on the transformation of chloro- and bromo-aminobenzenes into halogen-anilides, and of nitroaminobenzenes into nitroanilines has been communicated In the case of the former compounds, it has been shown that the transformation is not an intramolecular change but consists

[1] *Trans. Chem Soc*, 1910, 97, 2634-2645.

of a primary reaction of the chloroamine and hydrogen chloride, the presence of which is essential, thus —

$$Ar.NClAc + HCl \rightleftharpoons Ar.NHAc + Cl_2 \longrightarrow ClAr.NHAc + HCl.$$

Whether a true intramolecular change is possible under certain conditions has not yet been discovered, but it must not be supposed that the possibility is excluded

The conversion of the nitroaminobenzenes into the isomeric nitroanilines offers a very marked contrast

(i) All acids, and not one specific substance, bring about the transformation The relative effectiveness of different acids is generally proportional to their activities in other processes Moreover, when no side-reactions occur, the speed follows an equation of the first order, and, for a monobasic acid, is proportional to the second power of the concentration, at least in aqueous and dilute acetic acid solution

(ii) Although there is evidence, but of no certain kind, that the nitration of another substance by a nitroamine can occur (for example, of acetanilide or 2 4-dichloroaniline by *s*-tribromonitroaminobenzene), under certain narrowly defined conditions, there is nothing corresponding to the remarkable chlorination of one anilide by the chloroamine of another, which has been described No radicle (ion) or substance which is a powerful nitrating agent appears to be free in the system

(iii) The solid crystalline nitroamine changes into the nitroaniline, the crystals of the latter apparently growing out of the former in the presence of gaseous hydrogen chloride in a P_2O_5-dry atmosphere [1]

(iv) Although nitrous acid appears during the transformation, and diazonium salts are produced, the presence of urea in the system does not affect in any way the speed or the products of the change

(v) The nature of the nitroamine and of the catalyst has a very marked effect on the extent of the side-reaction in which the diazonium salt is produced The maximum amount of diazonium salt is found with 2 4-dichloronitroaminobenzene, much less with the corresponding 2 4-dibromo compound, and none with 1-methyl-3-bromo-4-nitroaminobenzene

The nature of the catalyst has a similar influence When nitric acid is the catalyst no appreciable quantity of diazonium salt can be found In the presence of perchloric acid, the maximum amount of diazo compound is produced, hydrogen chloride yields less and sulphuric acid still less The ratio of diazonium salt to nitroaniline for a given catalyst appears to be independent of the concentration of the catalyst or the composition of the medium, thus in the case of hydrogen chloride and 2 4-dichloronitroaminobenzene in various mixtures of acetic acid and water, the ratio, nitroaniline/diazonium salt = 3 7/1

Conclusion —So far as the evidence goes, the provisional conclusion may be drawn that the conversion of nitroaminobenzenes into nitroanilines differs from the conversion of chloroamines, and may probably

[1] *Reports*, 1909.

be regarded as an intramolecular change. But the possibility that under certain conditions a cleavage into aniline and a nitrating substance occurs, at least partly, cannot be excluded. Thus as an instance *s*-trichloronitroaminobenzene in an environment when transformation is generally rapid, yields largely *s*-trichloroaniline.

In the substances which we have closely investigated, one ortho-position only is vacant, into which the nitro group can migrate. The migration of the nitro group into the para-position is observed in the conversion of 2 · 6-dibromonitroaminobenzene into 2 · 6-dibromo-4-nitroaniline, this change is, however, accompanied by the formation of about an equal amount of the isomeric 2 · 4-dibromo-6-nitroaniline, the bromine atom in the ortho-position being displaced.[2] From a consideration of the relative proportions of *o*- and *p*-nitro-anilines and -anilides produced under various conditions, in the transformation of nitroamines, nitration by acetyl nitrate, &c., Holleman[3] has concluded that the ortho-compound is generally formed by way of the nitroamine, whilst the para-compound is formed by some other process. In the case above cited, however, the *p*-nitroaniline is undoubtedly obtained from the nitroamine, although perhaps not by a simple intramolecular re-arrangement. Comparison of the two changes shows at least that the conversion to the *o*-nitroaniline is a far more rapid and easy process.

Formation of Nitroaminobenzenes.—Owing to the difficulties of following further the conversion of nitroamines into nitroanilines, we have been led to study the conditions and mechanism of the formation of nitroamines. An excellent way of converting anilines into nitroamines is by treatment in acetic acid solution with a mixture of nitric acid and acetic anhydride (Orton[4] and Orton and Edwards[5]). The behaviour of nitric acid offers in this respect a marked contrast to that of other strong acids, they are powerful accelerators of the direct reaction between the anhydride and anilines (Orton and Smith).[6] In order to investigate these highly distinctive reactions more closely a means of determining acetic anhydride in such systems was required. A good method was finally devised (Edwards and Orton[7]) which is based on the following reactions, certain anilines, for example, 2 · 4-di-chloroaniline, react with acetic anhydride in acetic acid solution, even containing a certain proportion of water, very rapidly and quantitatively, the anilide is extracted from the diluted medium with chloroform and the excess of aniline removed by treatment with an acid, finally the anilide is converted into a chloroamine which can be estimated by titration. In this manner very small quantities of acetic anhydride can be estimated in the presence of acetic acid.

With the aid of this method of analysis, the hydrolysis of acetic anhydride has been studied and remarkable differences between nitric and other acids, in their effect on this process, discovered.

[2] Orton and Pearson, *Trans. Chem. Soc.*, 1908, **93**, 725.
[3] *Ber. d. deutsch. Chem. Gesel.*, 1911, **44**, 704.
[4] *Trans. Chem. Soc.*, 1902, **81**, 806.
[5] *Reports*, 1911.
[6] *Trans. Chem. Soc.*, 1908, **93**, 1242; 1909, **95**, 1060.
[7] *Ibid.*, 1911, **99**, 1181.

II *Hydrolysis of Acetic Anhydride* (With MARIAN JONES, B Sc)

So far the hydrolysis of acetic anhydride has only been investigated in aqueous solution by Menschutkin and Vasilieff, Lumière and Barbier (these investigators used a titrimetric process), and Rivett and Sidgwick [8] (using the change of electric conductivity) With the aid of the method above described, it is possible to follow this reaction in various media, and in the presence of catalysts

(i) *Hydrolysis in Aqueous Solution* --The table shows typical results of experiments when three different methods of measurement are used

TABLE I

Lumière and Barbier		Rivett and Sidgwick			Orton and Jones	
A	$k_I^{15°}$	A	$k_I^{25°}$	$k_I^{15°}$	A	$k_I^{15°}$
0.491	0.0735	0.487	0·1383	0.074	0.486	0.074
		0.265	0.1484	0.0793	0.269	0.084
		0.058	0.1561	0.0835		
0.491	$k_I^{0°}=0.03$				0.495	$k_I^{0°}=0.028$

On the supposition that the reaction is represented by the equation $Ac_2O + H_2O = 2CH_3.CO_2H$, the velocity factor, k_I = the product of the velocity co-efficient, k_{II}, of this reaction of the second order, and the concentration of the water, which is perceptibly constant,

$$= \frac{1}{t} \log e \frac{A}{A - x},$$

where A is the initial concentration of the anhydride in moles, and x the amount changed in time t (minutes)

(ii) *Effect of Medium* —Table II shows the effect of the composition of the medium on the rate of hydrolysis

TABLE II

Medium	Temperature	Concentration of Acetic Anhydride	Velocity-coefficient or Velocity-factor
Glacial acetic acid .	16	0.0804 ($[H_2O]=0.18$)	$k_{II}=0.00042$
95 per cent acetic acid	16	0.0782	$k_I=0.001$
90 ,, ,, .	16	0.0815	0.0028
80 ,, ,, .	16	0.0813	0.0056
50 ,, ,, .	15	0.083	0.016
Water . . .	15	0.473	0.074
95 per cent. aqueous acetone	15	0.087	6% hydrolysed in 118 hrs.
50 ,, ,,	15	0.088	$k_I=0.006$
Acetic anhydride . . .	15	10.3 ($[H_2O]=1.8$)	$k_{II}=0.000071$

[8] *Trans Chem. Soc*, 1910, **97**, 733, 1677.

As the acetic acid is diluted, the rate of hydrolysis increases roughly proportionally to the amount of water in the medium It is remarkable that pure acetic anhydride should be such a curiously unfavourable medium for its own reaction with water

(iii) *Effect of Catalysts* —In aqueous solution alkalis are very powerful catalysts of the hydrolysis Acids have, on the other hand, but a very feeble effect Such slightly hydrolysed salts as sodium acetate occupy an intermediate position

In anhydrous media acids produce a great acceleration of the reaction, but the effect diminishes as the proportion of water in the medium decreases

TABLE III.

Medium	Concentration of H_2SO_4	Concentration of Ac_2O	Temperature	Speed of Hydrolysis
			°	
Glacial acetic acid	—	0 0804	16	12% in 24 hrs $k_{II} = 0\ 00042$
	0 002M	0 077	16	52% in 10 mins
90 per cent acetic acid	—	0 0815	16	$k_1 = 0\ 0028$
	0 0166M	0 0807	16	0 016
	0 1M	0 091	15	0 076
50 per cent acetic acid	—	0 083	15	0 016
	0 034M	0 0835	15	0 03

With regard to the nature and concentration of the acid, it is to be noted that —

(i) In 90 and 95 per cent acetic acid molecular quantities of acids are equivalent in accelerating effect

(ii) In 50 per cent acetic acid equivalent quantities of acids produce equal effects

(iii) At intermediate compositions of the medium there is no simple relation

(iv) When the effect can be measured as in 90 per cent acetic acid, the rate of hydrolysis is found to be proportional to the concentration of the catalyst

These relations indicate that the unionised acid is the effective catalyst in media containing 90 per cent acetic acid and upwards, but that the ionised acid is the catalyst in media containing 50 per cent acetic acid

Nitric Acid as Catalyst —In its relation to the hydrolysis of acetic anhydride, nitric acid occupies a unique position Whilst in 50 per cent acetic acid its effectiveness is identical with that of other acids, as the proportion of water in the medium decreases, its relative activity steadily falls off, until in glacial acetic acid it is, compared with sulphuric acid, infinitesimal

TABLE IV.

Medium	Catalyst	Concentration of Ac_2O	Speed of Hydrolysis
50 per cent. acetic acid .	—	0 083	k_1=0·016
	0 034M H_2SO_4	0 084	0 021
	0 07M HCl	0 083	0 022
	0 071M HNO_3	0 087	0 022
90 per cent acetic acid. .	—	0 0815	0·0028
	0·033M HCl	0·081	0·023
	0 0165M HNO_3	0 083	0 0065
	0 033M HNO_3	0 0805	0 008
	0 066M HNO_3	0 079	0 012
Glacial acetic acid . . .	—	0 0804	12% in 24 hrs
	0 002M H_2SO_4	0 077	52% in 10 mins
	0 05M HNO_3	0 08	32% in 24 hrs.

Nitric acid only acts as other acids when ionised, the abnormality appears when the acid is partially or wholly unionised On diluting a solution of glacial acetic acid containing nitric acid to 50 per cent acetic acid, hydrolysis follows at the same rate as if nitric acid had been added to acetic anhydride dissolved in a 50 per cent acetic acid This result does not suggest that the formation of such compounds as acetyl nitrate, CH_3 CO O NO_2, or diacetylorthonitric acid, $(CH_3\ CO)_2N(OH)_3$, which have been described by Pictet and others, is the immediate cause of the peculiarity For it would then be necessary to assume that these compounds yield acetic anhydride and nitric acid on diluting the medium with water Moreover, the fact that the addition of a trace of sulphuric acid to the system containing nitric acid in glacial acetic acid is followed by the usual very rapid hydrolysis, indicates that the condition of the nitric acid only, and not that of the acetic anhydride, is the cause of the peculiarity

Discussion of Results —The suggestion, in a discussion of Rivett and Sidgwick's results in the Annual Reports of the Chemical Society (1910), that the mechanism of the hydrolysis of acetic and other anhydrides was not different from that of amides, esters, &c , as these authors had supposed, has been verified by our experiments Since the reaction of acetic anhydride with hydroxy compounds (Franchimont, Skraup, and others), and with amino compounds, weak bases (Orton and Smith), is enormously accelerated by strong acids, it was to be expected that its reaction with water would be similarly influenced

In recent years the mechanism of such reactions has received much attention, and it has been shown, more especially in the case of esterification (Lapworth, Goldschmidt, and others), that the reaction may proceed in various ways, depending on the medium, presence or absence of other substances (acids and other catalysts) Following the suggestion of these researches the hydrolysis of acetic anhydride may be represented by one or other of the equations:—

(i) $Ac_2O + H_2O = 2AcOH$,
(ii) $Ac_2O + H_2O + H^{\cdot} = 2AcOH + H^{\cdot}$,
(iii) $Ac_2O + H_2O + HX = 2AcOH + HX$;
(iv) $Ac_2O + H_2O + (OH)' = 2AcOH + (OH)'$

The third component, $H^{\cdot}$, OH', or HX, may exert its influence by forming a reacting ionic or non-ionised complex with one or other of the two reagents

In aqueous solution the choice lies between (i), (ii), or (iv) Strong acids have a feeble, whilst bases and even such a slightly hydrolysed salt as sodium acetate have a powerful, catalytic effect These relations suggest that in aqueous solutions hydroxyl ions play the predominant part. In that case traces of acids by decreasing the concentration of the hydroxyl ion should have a great retarding influence It is true that acetic acid does slightly retard the hydrolysis, but we have not found any such effect with sulphuric Hence, although hydroxyl ions are powerful catalysts, it may be concluded that in pure water the hydrolysis mainly follows equation (i) and is non-catalytic

In relatively anhydrous media, reaction (iii) obviously predominates The reaction is very slow in the absence of acids, molecular quantities of acids are equally effective, and the speed is a linear function of the concentration of the acid

In media such as 50 per cent acetic acid or acetone, the catalytic effect is now due to the hydrogen ions (equation ii) for equivalent quantities of acids are now of equal influence, but inasmuch as the rate of hydrolysis is considerable in the absence of an acid catalyst, the reaction also follows equation (i)

In media with less than 50 per cent of water the catalytic effect of acids follows both equations (ii) and (iii)

It is worthy of note that the velocity factor of the reaction is not independent of the initial concentration of the acetic anhydride, the value falling as the initial concentration increases This fact was observed and commented on by Rivett and Sidgwick, and is deducible from Lumière and Barbier's results for aqueous solution In our measurements the same fact is obvious both in aqueous and in 80 per cent acetic acid Thus for the initial concentration 0·486 and 0 269 molecule the value of $k_{\mathrm{I}}^{15^\circ}$ is 0 074 and 0 084, respectively, in aqueous solution; in 80 per cent acetic acid, $k_{\mathrm{I}}^{15^\circ}$ is 0 0047 and 0 0056 for the initial concentrations 0 1625 and 0 0813 molecule respectively When log k is plotted against log c (the concentration) for a series of values of c (between 0 1169 and 0 3947), selected from Rivett and Sidgwick's measurements, approximately a straight line is obtained Burke and Donnan [9] have observed a similar phenomenon in the reaction of silver nitrate and alkyl iodides, except that that value of k increases with increase of the concentration (of the silver nitrate) Here also log k and log c are linearly related, and hence the variation is expressed by the exponential law, $k = Kc^n$.

III *Some Properties of Acetic Anhydride* (With Marian Jones, B Sc)

Both our own experience and a study of the literature show that the complete separation of acetic acid and acetic anhydride, and hence the preparation of pure acetic anhydride is no simple matter Fractionation

[9] *Trans. Chem. Soc.*, **1904, 85, 555.**

without a still-head of a mixture containing only 10 per cent of acetic acid will give but some 8 to 10 per cent of pure anhydride By use of Young's 'pear' still-head the pure substance, amounting to 50 to 60 per cent of the original material, can be readily obtained Its physical constants differ materially from those usually given, Landolt's values alone agree with ours The boiling point is 139 55° under 760 mm pressure, and the density 1·0876 at 15°/4°, and 1 082 at 20°/4° The refractive index for H^c at 15° is 1 39069 At 15° about 2 7 grams of water dissolve in 100 grams of acetic anhydride, and 12 grams of anhydride in 100 grams of water

Action of Halogens on Acetic Anhydride —When light is excluded solutions of chlorine and bromine in acetic anhydride are quite stable But in the presence of strong acids, iodine, ferric chloride, &c , a very rapid reaction follows

TABLE V

$H_2SO_4 = N/3000$		$I = N/300$		$FeCl_3 = N/535$	
Time (Min)	Titre of 5 c c in N/50 Thiosulphate	Time (Min)	Titre of 5 c c in N/50 Thiosulphate	Time (Min)	Titre of 5 c c in N/50 Thiosulphate
	c c		c c		c c.
0	12 4	0	9·4	0	10·7
36	7 35	5	9 1	8	8 7
75	4·1	45	2 05	12 5	7 2
112	2 5			34	0·1

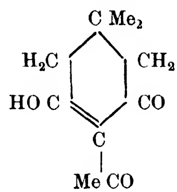
The catalysts are effective as the first power of their concentration, when acids can be compared—for example, sulphuric and perchloric—it is found that molecular and not equivalent quantities are equally effective

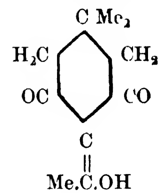
The fall in titre of the bromine is independent of the initial concentration of the solution, and hence bears a linear relation to the time, that is, the graph of dx/dt is a straight line Lapworth accounted for an exactly similar relation in the attack of bromine on acetone by supposing that the bromine only reacts with a tautomeride of acetone, the production of which from the acetone is far slower than its reaction with bromine The rate of disappearance of the bromine is dependent, therefore, only on the formation of the tautomeride, and independent of the concentration of the bromine In the case of acetic anhydride the reactive material is only formed in the presence of the catalyst Hence the speed of the bromination, which is proportional to the concentration of the former, must obviously also be proportional to that of the catalyst There is no such detectable acceleration of the action of bromine on acetic acid by acids (except possibly when their concentration is very high), hence it may be deduced, a similar reactive substance is not produced, at least to a proportionate extent, from acetic acid under the influence of acids

The Study of Hydro-aromatic Substances.—Report of the Committee, consisting of Professor A. W. CROSSLEY (*Secretary*), Professor W. H. PERKIN, Dr. M. O. FORSTER, *and* Dr. H. R. LE SUEUR.

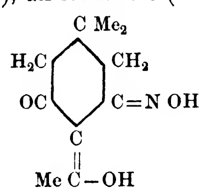
1. *The behaviour of c-acetyldimethyl- and c-acetyltrimethyldihydroresorcins towards hydroxylamine and phenylhydrazine.*—It has been pointed out[1] that trimethyldihydroresorcin does not behave towards many reagents in a similar manner to dimethyldihydroresorcin, for it exhibits tautomeric forms and also its molecule is not symmetrical. In order to clear up several points of interest the c-acetyl derivatives of these two dihydroresorcins are being investigated.

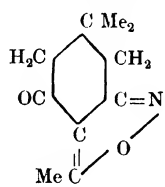
C-acetyldimethyldihydroresorcin behaves as a monobasic acid and may be represented by one or other of the following formulæ, probably

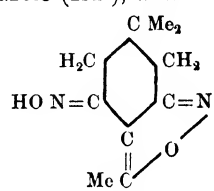




the second. When acted on by hydroxylamine it gives an acid oxime (I.), an isoxazole (II.), and an oxime of the isoxazole (III.), and with


I


II


III.

phenylhydrazine it behaves in a similar manner giving an acid phenylhydrazone, a phenylpyrazole, and a phenylhydrazone of the phenylpyrazole.

The behaviour of *c*-acetyltrimethyldihydroresorcin towards hydroxylamine has not been investigated owing to the fact that the isoxazole is a liquid or very low melting solid, but with phenylhydrazine it gives an acid phenylhydrazone and a phenylpyrazole, though all attempts to prepare a phenylhydrazone of the phenylpyrazole have so far failed. It is presumed that c-acetyltrimethyldihydroresorcin is similarly constituted to the corresponding derivative of dimethyldihydroresorcin, but the results will be discussed at length in another publication.

2. *The action of phosphorus pentabromide on dimethyldihydroresorcin.*—In 1903 it was shown[2] that phosphorus pentabromide acts on dimethyldihydroresorcin to give several bromodimethylcyclohexanones and also certain bromoxylenols. One of the latter substances (melting-point 96-97°) was thought to be a derivative of 1·2-xylenol-3, and this has now been definitely shown by synthesis which proves it to be 4. 5-dibromo-1: 2-xylenol-3. The formation of this substance

[1] *J.C.S.*, 1911, **99**, 1101. [2] *Ibid.*, **83**, 110.

necessitates the wandering of a methyl group into an ortho position, and several instances of similar reactions have already been recorded A closer investigation of the reaction shows that apparently derivatives of 1·3-xylenol-4 are also formed and at first sight this would appear to mean that a methyl group had wandered into a meta position There is, however, another possibility If one methyl group can wander into an ortho position why, under certain conditions, should not both methyl groups wander into ortho positions, thus giving rise to a 1 3-xylenol?

The reaction is very complicated and not easy to work out, owing to the difficulty of separating the mixture of bromoxylenols produced At the present time attention is being particularly directed to the synthetic formation of those bromoxylenols which appear likely to be produced in the reaction, as very few of these substances are described in the literature

Composition and Origin of the Crystalline Rocks of Anglesey — Seventh Report of the Committee, consisting of Mr A Harker *(Chairman)*, Mr E Greenly *(Secretary)*, Dr J Horne, Dr C. A Matley, *and* Professor K J P Orton

In presenting this, their final Report, the Committee desire to summarise briefly the work that has been done since their appointment Work was begun in the summer of 1905, and has been proceeding ever since, but the time that Mr J O Hughes' duties as demonstrator in the University College of North Wales has allowed has never been very great, and progress has consequently been slow, the more so as modern methods of silicate analysis make very heavy demands upon time.

Altogether about 80 rocks have been analysed, 12 qualitatively, 68 quantitatively Of the quantitative analyses, 43 have been complete, the others partial As a certain number of older analyses are also available, it is probably safe to say that the rocks of hardly any other, perhaps no other, district of the same size will have received so much attention from the chemical point of view as those of Anglesey

The Committee also desire to express their very great obligations to Mr Hughes, without whom the work would have been quite impossible Indeed, it is not too much to say that the work of the Committee is the work of Mr Hughes (That of the Secretary has been confined to selecting the subjects for analysis and collecting the material in the field) Of the analyses enumerated, all but a few have been made by him, and all the complete ones are his work The total number of estimations that have been made is about 730, and of these 39 are by other hands, so that Mr Hughes has made for the Committee 691 estimations Only those who have had some experience of the analysis of rocks, especially of silicates, will be able to appreciate the patient care involved in such work, carried on unremittingly through seven years Nor will any but those who have had occasion to deal with the baffling problems presented by the crystalline schists be wholly able to appreciate the value of Mr Hughes' contribution to petrological science in general and to our knowledge of the rocks of the British islands in particular

The thanks of the Committee are also due to the University College

of North Wales, for, at the outset of the work, the College generously fitted out a special laboratory in which it should be carried on

When the last Report was presented Mr Hughes was, as therein explained, carrying on his work in the laboratory of the Geological Survey, and most of the analyses that will now be given were made in that laboratory

No 436 A Tremolite Schist, Cerig Efa, Rhoscolyn

	I	II
SiO_2	53 66	53 64
TiO_2	0 06	0 06
Al_2O_3	3 24	3 25
Fe_2O_3	3 47	3 49
FeO	3 89	3 87
MnO	0 14	0 11
CaO	9 24	9 22
MgO	24 50	24 52
K_2O	Nil	Nil
Na_2O	0 51	0 50
H_2O (at 110°)	0 03	0 04
H_2O (above 110°)	1 36	1 35
	100 10	100 05

No 775 A Tremolite Marble, Gareg Lwyd, Rhoscolyn

Mr Hughes remarks 'It was pointed out in a previous Report that the usual method of digesting with hot HCl does not appear very suitable for the analysis of metamorphic limestones containing silicates In the case of the ophicalcite from Rhoscolyn it was found difficult to obtain concordant values, even when the rock-powder was digested with HCl of exactly the same concentration for the same periods of time The same difficulty has again been experienced in the case of this tremolite marble, and the following analyses tend to strengthen the view expressed at that time that acetic acid is a more suitable reagent in such cases '

Digestion with HCl

	I	II
Residues insoluble in 20% HCl	26 70	29 28
Soluble SiO_2	0 22	0 10
$Al_2O_3+Fe_2O_3$	4 53	3 23
MnO	0 36	0 28
CaO	26 85	26 88
MgO	10 29	9 24
CO_2	29 41	29 46
H_2O	undetermined	
	98 36	98 47

Digestion with Acetic Acid.

	I.	II.
Residues insoluble in acetic acid	34 47	34 42
Soluble SiO_2	Nil	—
$Al_2O_3 + Fe_2O_3$	0 42	0 44
MnO	Nil	—
CaO	26 83	26 86
MgO	7 51	7 53
CO_2	29 44	29 40
H_2O	1 12	1 18
	99 79	99 83

The tremolite schist and tremolite marble are part of the exceptional group to which the ophicalcite belongs, associated with the serpentine and gabbro of the Holyhead area

Cf 494 A Holy Isle, East of Trearddur Bay

	I	II.
SiO_2	72 30	72 35
TiO_2	2 53	2 54
Al_2O_3	10 21	10 25
Fe_2O_3	2 31	2 30
FeO	2 62	2 62
MnO	0 20	0 22
CaO	2 69	2 66
MgO	1 26	1 34
K_2O	0 82	0 78
Na_2O	3 04	3 12
H_2O (at 110°)	0 09	0 09
H_2O (above 110°)	1 67	1 67
	99 74	99 94

This is from one of the hard bands in the mica schists, an extensive formation about Holyhead

Cf 363 A Brynlirion, Holyhead

	I	II
SiO_2	48 50	48 54
TiO_2	2 74	2 73
Al_2O_3	23 23	23 28
Fe_2O_3	4 17	4 16
FeO	5 66	5 68
MnO	0 16	0 15
CaO	1 45	1 51
MgO	3 31	3 28
K_2O	5 96	5 93
Na_2O	0 91	0 98
H_2O (at 110°)	0 12	0 12
H_2O (above 110°)	3 81	3 82
	100 02	100 18

This is from one of the micaceous, fissile seams in the same mica schists as those from which Cf 494 A was taken, and is intended to bring out the difference between the two leading types of material in those schists, which are of sedimentary origin At the same time they are intended to compare with some of the mica schists of doubtful origin that occur in the central and south-east areas of the island

No 747 A Traeth Dynion, Amlwch

	I	II
SiO_2	67 16	66 98
TiO_2	0 69	0 69
Al_2O_3	14 80	14 79
Fe_2O_3	6 34	6 32
FeO	0 80	0 82
MnO	0 27	0 26
CaO	1 15	1 13
MgO	2 22	2 25
K_2O	1 87	1 84
Na_2O	3 50	3 52
H_2O (at 110°)	0 06	0 08
H_2O (above 110°)	1 79	1 78
	100 65	100 46

This is one of the rocks composed of purple phyllite rapidly alternating with bedded jasper. Both types are included in this analysis, but there is more of the jasper than of the phyllite

770 A Traeth Dynion, Amlwch (Fissile part of Amlwch schist)

	I.	II.
K_2O	3 60	3 63
Na_2O	2 87	2 96

This is the fissile type that forms part of the Amlwch schists, corresponding to the similar part of the schists of Holyhead. The hard part is really fine grit, but has not yet been analysed

741 A. Variolitic Pillowy Diabase, Amlwch

	I.	II.
SiO_2	39·18	39 22
TiO_2	2·21	2·20
Al_2O_3	18·81	18·79
Fe_2O_3	8·62	8·61
FeO	4·99	5·01
MnO	Nil	Nil
CaO	9·70	9·69
MgO	10 02	10 05
K_2O	0·18	0·15
Na_2O	1·87	1·89
H_2O (at 110°)	0 10	0·10
H_2O (above 110°)	4 52	4·54
	100 20	100·25

This rock should be compared with the similar rock analysed some time ago and published in a former Report The types differ considerably

Cf 82 A Holland Arms Railway Cutting, Dolerite

	I.	II.
SiO_2	46 43	46 46

This is from the Holland Arms Main Dyke, one of the later dykes of the island

Specific gravities have been taken of the following basic dykes, and also of two other basic rocks:—

Specific gravities

Holland Arms Main Dyke		2 948
Holland Arms Minor	,,	2 852
Plas Newydd	,,	2 966
Graig Fach	,,	2 948
Garth Lodge	,,	2 785
Pont Dick	,,	2 987
Castellor	,,	2 985
Yr Allt	,,	2 979
Mynydd Mechell (*a*)	,,	3 029
Mynydd Mechell (*b*)	,,	2 954
Wylfa	,,	2 805
Pillowy Diabase, Cerig Ceinwen		2 825
Dolerite, Three Lakes		2 894

Most of the rocks that have been analysed have been from the great schistose complex. Some from other systems have also been selected,

but the most valuable part of the analytical work is that which bears upon the schistose complex, because of the genetic problems it presents. Moreover, that interest is by no means merely local, for similar types are found in other metamorphic districts There is often, in such districts, a difficulty in distinguishing schists of igneous from schists of sedimentary origin, not to speak of mixed types, which certainly occur In such cases the evidence of the microscope may be inconclusive, and resort must be had to chemical analysis. But this is too tedious and difficult to be applied with freedom Every case, therefore, in which the mineral composition and microscopic structure of a rock have been correlated with its chemical composition constitutes a standard for rocks of similar mineral composition and structure. The difficulty is, naturally, with the acid schists, and, as Anglesey contains mica schists that are, so far as can be ascertained, of both igneous and sedimentary origin, it is hoped that the evidence that has been gathered in the course of the work of this Committee will be of use in the study of the crystalline schists as a whole

---

Bembridge Limestone at Creechbarrow Hill.—Report of the Committee, consisting of Professor T McKenny Hughes (*Chairman*), Mr. H Woods (*Secretary*), Dr. J J H Teall, Dr. J. E. Marr, Professor E J. Garwood, Mr. Clement Reid, Mr. W. Whitaker, *and* Mr H A Allen, *appointed to investigate the Occurrence of the Bembridge Limestone at Creechbarrow Hill.*

On the Results of the Further Examination of Creechbarrow Hill By Henry Keeping

In September 1910 I was sent by Professor Hughes to collect fossils on Creechbarrow, with a view to determining the age of the limestone which caps the hill In that principal object I was successful, as I obtained a sufficient number of characteristic forms to enable me to refer the rock to the Bembridge Limestone

The collection is now in the Sedgwick Museum

In the report which I then published [1] I further suggested that there was plenty of room for the rest of the Tertiary beds which might be expected to occur below the Bembridge Limestone, and I published a section in illustration of that view

I had not, however, then any data to justify the statement that the rest of the Tertiary beds did occur in regular sequence below the Bembridge Limestone of Creechbarrow, and therefore confined myself to the statement that there was plenty of room for them, as I knew them in the adjoining areas, and allowing for such modifications of thickness as commonly occurred in the district

I regretted leaving the matter in that unsettled state, and applied

[1] *Geol Mag*, Dec v vol vii, October 1910

for a grant from the British Association to enable me to follow up this second line of inquiry and to endeavour to ascertain, by means of excavations and borings, what beds really did occur along the flank of the hill.

As soon as I obtained permission I commenced work so as to avail myself of the longer days and better weather. I first opened four pits on the east side from about 12 feet from the summit to about 130 feet down the flank of the hill. The total aggregate thickness of strata passed through in these trial holes was 85 feet 3 inches. I then sunk and bored to a depth of 34 feet on the opposite or west side of the hill, starting at 10 feet from the summit.

The details of the section were as follows:—

PIT I (*the highest on the east side of the hill*)

	Ft.	in.
(*a*) Surface soil		
(*b*) Mixed clay and gravel with sharp angular flints .	3	0
(*c*) Blocks of hard limestone with Melanopsis and Paludina	2	0
(*d*) Rubbly limestone. This I at once recognised as the same as the bed which occurs at the base of the limestone on Headon Hill, where it is rich in mammalian remains. I found here a tooth of Palæotherium on my last visit, and we now obtained a good tooth of *Dichobunus leporinus* (Owen) .	0	9
(*e*) Caking sand	3	6
(*f*) Dark brown sand	14	6
(*g*) Light grey sand with a very large flint at the base. This is on the same horizon as the bed in which Mr. Huddleston found the curiously coated flints which he thought were *in situ* and passed under the limestone	1	3
	25	0

PIT II

	Ft.	in.
(*a*) Surface soil		
(*b*) Clay, sand, and gravel with fragments of weathered limestone at the bottom	16	0

PIT III

	Ft.	in.
(*a*) Surface soil		
(*b*) Dirty gravel . .	3	0
(*c*) Caking sand . .	3	0
(*d*) Large and small flints . .	1	0
(*e*) Brown, stiff, sandy clay . .	3	0
(*f*) Loose flint gravel	2	0
(*g*) Black streaky clayey sand with flint-chips, concretions, and much manganese . . .	7	0
(*h*) Hard irony crust . . .	0	3
(*i*) Clayey sand with perished flints; one large white flint at the bottom of the hole	0	3
	19	6

PIT IV.

	Ft.	in.
(*a*) Vegetable mould	0	9
(*b*) Clay, sand, and gravel with very large flints up to 1 cwt. This much resembles the Middle Headon Venus Bed .	9	0
(*c*) Drab sandy clay like that in brickyard, not bottomed	15	0
	24	9

Pit V (*about* 10 *feet below the summit on the west side of the hill*).

	Ft	in.
(*a*) Surface soil.		
(*b*) Clay with angular flints	2	6
(*c*) Very stiff hardened clay with pieces of rubbly limestone containing much manganese and soot-like patches . . .	9	6
(*d*) Fragments of Bembridge Limestone very rich in fossils This was where I obtained the chief collection made during my former visit On this occasion we obtained a good specimen of Unio, the first, I believe, found at this horizon . .	2	0
(*e*) Hard crumbling limestone	7	0
(*f*) Sandy clay	9	0
(*g*) Grey sands with quartz pebbles and broken flints On my former visit I found a large fragment of Bembridge Limestone at a depth of 13 feet not far from this pit This specimen is now in the Sedgwick Museum	4	0
	34	0

The lowest bed we touched was the drab sandy clay at the bottom of Pit IV, which is the same as that seen in the brick-pit, and the thickness of which I estimate to be not less than 40 or 50 feet. It seems to have been much used for dressing the land, and we found many old pits from which it had been obtained along the west side of the hill This clay I regard as the equivalent of the Lower Headon formation The coarse sand, which occurred above this, I take to be the Middle Headon Venus Bed, while the mottled red and green clays or marls which we found about 16 feet below the summit of the hill much resembled the Osborne Series.

Of the part of the hill explored by us I should say that about three-quarters consisted of Oligocene Strata and the rest of sand and gravel

There is everywhere evidence of great disturbance of the strata, whether we refer this chiefly to large movements of faulting and overthrust, or the more superficial action of landslips, soil creep, &c. The result has been a kneading up together of various deposits, so as to produce in many parts a mass much resembling some boulder clays. In fact, when I noticed the same kind of boulder clay at the bottom of the St Erth Beds, being familiar with the great masses of ice-transported rock further north, I often felt inclined to ask whether the limitation of the southerly extension of ice action was so certain as is generally assumed. But I am also acquainted with the great earth movements affecting our south coast, and with the ever-recurring landslips along such an escarpment as we have at Creechbarrow. I do not, therefore, feel inclined to press any explanation here without further evidence

In conclusion, I may be allowed to offer my thanks to Mr. Bond, the owner of the property, and to Mr Trent, his tenant, for kind permission to carry on the work; also to Mr. Pike and Mr. Bloomfield for much information and assistance.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Mr R. H. TIDDEMAN (*Chairman*), Dr. A. R. DWERRYHOUSE (*Secretary*), Dr. T. G. BONNEY, Mr. F. W. HARMER, Rev S N. HARRISON, Dr J. HORNE, Mr. W. LOWER CARTER, Professor W. J SOLLAS, *and* Messrs. WM HILL, J W STATHER, *and* J. H. MILTON.

ENGLAND

Reported by the Northumberland and Durham Boulders Committee of the University of Durham Philosophical Society

1 *Reported by* G WEYMAN, *B Sc* —

(*a*) Boulder clay, Kenton Quarries. Greywacke (3), porphyrite, Cheviots (2), Cheviot granite, grey granite, Crystalline limestone, quartz porphyry

(*b*) Gravel deposit, Horsebridge Head, Newbiggin Flints (2), quartzite schist (2), quartz porphyry, granite (3), Cheviot granite, syenite (4), mica porphyrite, chert, andesite; breccia

(*c*) Boulder clay, Tynemouth Greywacke, granite (2); syenite, porphyrite, micro granite

(*d*) Blue clay, Tynemouth. Volcanic series of Borrowdale, granite

(*e*) Vicarage Burn, Barrington Granite

2 *Reported by* F WALKER, *B Sc* —

(*a*) Boulder clay, Armstrong Park, Heaton · Cheviot granite

(*b*) Standard Brick Works, Heaton. Basalt, dolerite, quartzite, calcareous grit

(*c*) Boulder clay, Monkseaton Granite, syenite, basalt, volcanic series of Borrowdale

(*d*) Corbridge Volcanic series of Borrowdale and granite

3 *Reported by* Dr WOOLACOTT —Aycliffe Quarries Resting on the limestone here is a blue stony clay, with sand, leafy clay, and yellow clay above The surface is striated 30° W of S In the stony clay boulders of Threlkeld granite and volcanic series of Borrowdale occur

4 *Reported by* F WALKER, G WEYMAN, *and* Dr WOOLACOTT — From Armstrong Whitworth's New Shipyard, Walker-on-Tyne · Granite (Criffel), several other granites; syenite; volcanic series of Borrowdale, whin, Carboniferous limestone (several), Magnesian limestone; brockram, sandstone, conglomerate (Tuedian ?)

5 *Reported by* Dr SMYTHE —Striations observed on Whin Sill 300 yards east of Northside, Kirkwhelpington Height 700 feet Direction E

Reported by the Rev A IRVING, *D Sc*, *and* Mr PERCY A IRVING, *B A* —

'Erratics found in the Boulder Clay at Harlow (Essex) '[1]

The following geological formations are represented:—

1 *Carboniferous Limestone* —Numerous blocks of various shapes (one block nearly a cubic foot). Examples: (*a*) Striated block

[1] See *Nature*, June 20, 1912

(11×9×6 inches); (*b*) Well-polished and striated block (9×8×2½ inches); (*c*) well-striated block (7×4×2½ inches); (*d*) Block of 'encrinital limestone' (8×5×3 inches) partly marmorised

1*a* *Millstone-grit* various and numerous towards the southern end of the 'till,' two miles south of Harlow, where it ends off abruptly upon the London clay *in situ*

2 *Permian*—Fragment of 'Rothschiefer' and marl-slate

3 *Bunter*—Quartzite and quartz pebbles (the largest 7 inches)

4 *Keuper.*—Calcareous basement breccia.

5 *Rhætic*—Traces of 'bone-bed' on slab of limestone

6 *Lias*—(*a*) Concretionary ironstone from the M Lias (one block 7×5×1½ inches), (*b*) Block of hard shelly limestone containing *Avicula inequivalvis*, *Ditrypa quinquecristata*, and plates of *Ostræa liassica* (?), (*c*) *Gryphæa incurva* (rather common), (*d*) *Pholodomya ambigua* (isolated and worn, (*e*) *Modiola* ? *gibbosa* as in the Lias of Kilsby (Northants); (*f*) *Ammonites* (*Ægoceras*) *angulatus* (?) dispersed on a slab of grey limestone

7 *Great Oolite*—Slabs of unfossiliferous limestone, very similar to beds exposed at Great Ponton

8. *Cornbrash*—Rounded block of tough shelly limestone (10×6×3 inches), angular block of more shelly limestone with *Pleuromya*, sp, and *Nucula Waltoni*

9 *Oxford Clay*—Calcareous nodules, shale containing small ammonites of the Jason group (as at Fletton, near Peterborough), *Amm varicostatus*, *Amm. vertebralis* (fragment); *Belemnites Oweni* (*puzosianus*) rather common, *Gryphæa dilatata*, *Gryphæa bilobata*

9*a* *Calcareous Grit*—Rolled fragment of cast of *Ammonites solaris* (*plicatilis*)?

10 *Kimmeridge Clay and Portland Sand*—*Ostræa deltoidea; Ostræa expansa*, *Ammonites biplex*, several fragments (one apparently complete in a large concretion) (12×10×4½ inches)

One fragment of Jurassic (?) Ammonite, sp (?)

11 *Purbeck*—Slab of argillaceous limestone with *Cyprides*, block of sulphurous limestone with lignite (10×6×3 inches), striated (no direct evidence of its geological age)

12 *Cretaceous*—Boulder of Red Chalk (Lincolnshire or Norfolk) (7×6×5 inches), boulders from the harder beds of the Upper Chalk, very common, often grooved and striated

13 Roughly cleaved Slate from Charnwood

Remarks—(1) Rolled sarsens and septaria from the Eocene are not reckoned as 'erratics' (2) The summit of the hill pierced by the sewerage-works is 252 feet, and here the boulder clay was pierced to 32 feet without reaching the bottom of the deposit Two rolled fragments of crystalline rock have been found more recently, both bearing a resemblance to some Derbyshire dolerites

NOTE—In the identification of the specimens assistance has been freely rendered by members of the staffs at the British Museum (Natural History) and at Jermyn Street Museum, and is here gratefully acknowledged. The works of the late John Phillips, F R S, and Robert Etheridge, F.R S., have been freely used.

Mr. H. Tooley, the Essex County Council's official, writes: 'In no instances have I seen the boulders and fossils so numerous as at Harlow, chalk being in some cases the only substance noticed in addition to the clay.'

The boulders and fossils have been presented for the most part to the Essex Museum at Stratford.

Reported by J. W. STATHER, *F.G.S., Hull Geological Society.*

Within the last few months I have received a collection of boulders and pebbles from the Dogger Bank, dredged by Hull trawlers, about 150 miles east of Coquet Island, off the Northumberland coast.

The larger boulders consist for the most part of coarse crystalline rocks (schist, gneiss, quartzite, quartz-porphyry, &c.), while among the pebbles are two or three varieties of fine-grained granite, porphyrite, basalt, and black flint.

As to the original source of these rocks I am unable to say anything with certainty at present, as few (if any) of them belong to types with which I am familiar in East Yorkshire; but I hope to be able, with the help of Scandinavian geologists, to locate at least some of them in the near future.

The boulders have been sent to me by the 'Admiral' of the Gamecock Fleet of Trawlers.

Reported by Mr. T. SHEPPARD, *F.G.S.*

The 'Hebbles' in the Humber Estuary.

Running parallel with the north shore of the Humber estuary a little to the east of the mouth of the River Hull, and at some distance from the shore, is a long submerged bank which considerably interferes with shipping.

A little while ago it was decided that this should be removed, and powerful dredgers were used. The material excavated has been transferred to another part of the estuary, and from an examination of this it is apparent that the bank instead of being an ordinary sand or mud bank, as was suspected, turned out to be of solid boulder clay. The boulders consisted of Carboniferous Limestone, Liassic and Oolitic fragments and fossils, Chalk, Basalts, Red Granites, &c., many of which are well striated. From the boulders and the clay it is apparent that the bank consists of the Middle Boulder Clay. Through the kindness of Mr. A. E. Butterfield, of the Humber Conservancy, I have been able to acquire a good selection of the boulders.

IRELAND.

Reported by ARTHUR R. DWERRYHOUSE, *D.Sc., F.G.S., M.R.I.A.*

County Antrim.

On main road between Coratavey Bridge and Torteig (5 miles S.E. of Ballycastle) [Sheet 8] (620 feet). Red granite, red quartzite, basalt, mica-schist (local), dolerite of Fair Head, red quartz-porphyry, vein-quartz (striated), Carboniferous sandstone.

Stream section below Torteig (430 feet): Brown sandy gravel with

mica-schist, chalk, flint, basalt, vein-quartz, red granite, red quartz-porphyry.

Stream section below Drumnacoll (340 feet): Section consists of

$$\left.\begin{array}{l}\text{3. Coarse gravel (water worn).}\\ \text{2 Current-bedded sand.}\\ \text{1 Red Boulder Clay}\end{array}\right\} = 100 \text{ feet.}$$

The bed (1) contains basalt, chalk, mica-schist, gneiss, vein-quartz, flint, and calcareous sandstone with lustre-mottling (Carboniferous).

Near Retreat Station, Glen Ballyemon [Sheet 14]. Country Rock—Basalt: In boulder clay, flint, chalk, Old Red Sandstone, Old Red Sandstone conglomerate, quartzite, mica-schist and vein-quartz.

Friar's Glen, three miles N.N.W. of Soldierstown [Sheet 36] (100 feet) Country Rock—Basalt: Hornblende diorite, quartzite, coarse red muscovite-granite, andesite These are all from the district round Pomeroy Also Carboniferous sandstone, flint, and vein-quartz

During the year thin sections of a number of Irish erratics have been prepared, and the Secretary has visited Arran and Bute with the object of ascertaining how far the rocks of those islands have contributed to the glacial deposits of the North of Ireland, and has collected a number of specimens for purposes of comparison It is hoped that the results of this investigation will be published in the next report of the Committee

---

The Preparation of a List of Characteristic Fossils —Interim Report of the Committee, consisting of Professor P. F Kendall (*Chairman*), Mr W Lower Carter (*Secretary*), Mr H L Allen, Professor W S Boulton, Professor G Cole, Dr. A R. Dwerryhouse, Professors J. W Gregory, Sir T H Holland, G A Lebour, *and* S H. Reynolds, Dr. Marie C. Stopes, Mr Cosmo Johns, Dr. J E Marr, Dr A. Vaughan, Professor W. W. Watts, Mr H Woods, *and* Dr A Smith Woodward, *appointed for the consideration thereof.*

Early in this year answers were received from the members of the Committee to the series of questions submitted to them for consideration by the Chairman and Secretary. These replies were codified and embodied in a circular letter which was sent in April to the members of the Committee and to a number of specialists in the palæontology of the various geological formations.

The members of the Committee unanimously approved of the suggestion that a small sub-committee of experienced teachers should be asked to draw up a list, in the first instance, for presentation to the Committee and the specialists. Some members, however, pointed out that the list of fossils adopted by the University of Cambridge, and which had stood the test of many years' practical use, was in print, and suggested that this might very conveniently be adopted as the basis

for the Committee's work, and so obviate a large amount of preliminary discussion This list had been prepared with special reference to the collections in the Sedgwick Museum and the local needs of the Cambridge student, but when this is taken into account it was felt that it would be a valuable aid to the work of the Committee Accordingly, by the kindness of Professor T McKenny Hughes and Mr. H Woods, copies of the 'Catalogue of the Fossils in the Students' Stratigraphical Series' of the Sedgwick Museum were circulated to the Committee and specialists along with the circular letter Up to the present a number of replies have been received, but others are still outstanding It is hoped that during the next year the complete lists may be received and embodied in a general list of fossils for the consideration of teachers of geology to whom it will be submitted

The Committee ask to be reappointed with a grant of *5l.*

The Excavation of Critical Sections in the Palæozoic Rocks of Wales and the West of England.—Report of the Committee, consisting of Professor LAPWORTH (*Chairman*), Mr W. G. FEARNSIDES (*Secretary*), Dr. J. E. MARR, Professor W. W. WATTS, *and* Mr G. J. WILLIAMS.

Fifth Report on Excavations among the Cambrian Rocks of Comley, Shropshire, 1911, *by* E S COBBOLD, *F G S*

I DEVOTED the grant made in 1911 to additional excavations in two parts of the area (A) South of Robin's Tump; (B) in the Comley Brook, where it has cut a little gorge between Dairy Hill and Hill House Ridge. The exact positions of all these excavations are recorded on my own field map, and the majority of them can be identified by the references given below to the map published with my report to the Sheffield meeting (1910)

(A) EXCAVATIONS SOUTH OF ROBIN'S TUMP

Excavation No 44, Westwards from the Spring

It was known that Bala Grits occurred at some little distance to the west of the Spring, where Excavation No 43 (Portsmouth Report) had proved the existence of shales with *Orthis* (*Orusia*) *lenticularis* (Wahlenberg) In the hope of finding higher horizons of the Cambrian a number of trial-holes, 3 to 4 feet deep, were opened at intervals along a direct line between the two points Shales similar to those at the Spring were proved for about 50 yards, but beyond this distance fragmentary green sandstone, referable to the Lower Comley Sandstone and, in one place, yielding obscure specimens of *Hyolithus*, occurred in every opening until the yellow Bala Grits were encountered

Though the actual line of contact between the shale and the sandstone was not observed, it is clear that they are separated by a fault at this point as well as close to the Spring, and the trace of this fault can be laid down on the map.

Excavation No 45, Southwards from the Spring.

Similar trial-holes were made at intervals upon the surface of the slope to the south of the Spring in the direction of another known exposure of Bala rock. In each instance the existence of Cambrian shale was proved, with here and there ill-defined examples of, probably, the same *Orthis*, but no fossiliferous band was observed The shale retained its general characteristics, but was so much crushed that dip and strike could not be satisfactorily determined within the limits of the shallow excavations. A nearer approximation to the line between the Cambrian and the Bala at this point can now be laid down on the map, but the actual contact was obscured by the presence of many large blocks of sandstone belonging to the younger series. If, as seems probable, the Cambrian shales retain the north and south strike observed near the Spring for a considerable distance, the Bala beds are strongly discordant to them, with a south-east and north-west trend.

(B) EXCAVATIONS ALONG COMLEY BROOK

The prolonged drought of the summer of 1911 provided an excellent opportunity for examining the beds of shale and sandstone which were known to occur in the bed of the Brook as well as in the slope above its left bank, and I was able to make considerable additions to our knowledge of the inter-relations of the various rocks and of their fossil contents.

The rocks composing the little elevation called Dairy Hill were proved in my first and second reports (Dublin 1908, and Winnipeg 1909) to be folded into a dome, consisting of a core of Lower Comley Sandstone (Lower Cambrian-*Olenellus* zones) with a covering of the Quarry Ridge Grits (Middle Cambrian-*Paradoxides* zones) The Comley Brook has cut into the western flank of this dome, and affords some poor natural exposures of its component rocks which are much obscured by vegetation The excavation work consisted principally of clearing away soil and herbage wherever rock was visible, with occasional pickaxe work in the rock itself

A straight line of fence (seen near the numbers representing Excavations Nos 12 and 13 on the map published with the Sheffield Report) forms the south-east boundary of the enclosure called Dairy Hill, and cuts the line of the Brook at right angles. This forms a convenient point from which measurements may be taken. The exposures in the bed of the Brook down-stream (north-west of this point) are described below as Excavation No 46, and those up-stream (south-east) as Excavation No 47

Excavation No 46, Comley Brook.

Opposite the fence above mentioned, brownish shale with bands of hard ringing grit, agreeing in character, strike, and dip with those of Excavation No. 13 (Dublin Report, 1908) are to be seen in the Brook.

At 18 yards to the north-west there is a mass of blue-grey, much fractured shale, weathering brown; at 36 yards similar shale with a strong westerly dip occurs, and has yielded a few small fossils, among which

I recognise *Lingulella*, *Acrotreta*, *Hyolithus*, and *Hyolithellus*[1]; at 38 yards a bed of hard ringing sandstone is seen; at 50 yards a thick bed of pebbly grit (6 or 8 feet seen) occurs in the bank The shales with the hard grit bands and the fossils almost certainly belong to the zone which I have previously called Quarry Ridge Shales, but the systematic position of the thick grit remains to be determined.

Excavation No. 47, Comley Brook.

On clearing out the bottom of the Brook to the south-east of the fence to Dairy Hill, green sandstones or sandy shale were met with almost continuously for about 90 yards, but, owing to the fact that the stream is almost parallel to the strike, no detailed section of the beds can be measured; they are therefore given in the table below as they occur in *horizontal plan* The strike is generally north-west and south-east and the dip south-west, but there are slight variations from these directions, showing that the beds are not steady

Distances from the fence in yards	General characters of the rock beds and their fossil contents	Rock Groups to which the beds are referred
From 0 to 6	Shale with hard ringing grit-bands	Quarry Ridge Shales (Middle Cambrian)
At 6 . . .	A north and south fault, cuts the beds obliquely	
At 7 . . .	Rather soft green sandstone	Lower Comley Sandstone (Lower Cambrian)
From 9 to 10 .	Similar sandstone with many fossils:— *Callavia Callavei* (Lapworth) *C. Cobboldi* (Raw MS) *Wannesia* (?), sp. *Microdiscus*, sp., cf. *M. Helena* (Walcot) *Ptychoparia* (?) *attleborensis* (S. and F.) *Hyolithus* (*Orthotheca*), sp. *Stenotheca*, sp , cf. *S. rugosa* (Hall) *Kutorgina cingulata* (Billings) ? *Linnarssonia*, sp. An orthid	
From 10 to 28	No solid rock seen	
From 28 to 30	Red and green sandy shale, reminiscent of that immediately below the *Olenellus*-Limestone of the Quarry	
From 30 to 67	Green sandstone and shaly sandstone of varying degrees of hardness, with occasional tracks or burrows of organisms and also with dark calcareous nodules at distances 49 and 67 yards	
From 67 to 90	No rock seen	
From 90 to 93	Green sandstone and shaly sandstone, dipping 45° westerly	

The fault at six yards, running obliquely across the bed of the Brook, is very distinct, the shale and green sandstone being seen in actual contact

[1] I use the term *Hyolithellus* for certain straight tubes of circular section comparable with *H micans* Billings, which are of frequent occurrence in both the Lower and Middle Cambrian beds of Comley.

The fossils at 9 to 10 yards are, in many cases, identical with those of the *Olenellus*-Limestone of the Comley Quarry, but are embedded in green sandstone instead of in the pinkish or red calcareous rock of the Quarry.

The red and green sandy shale at 28 to 30 yards is so like the rock immediately below the *Olenellus*-Limestone of the Quarry (see Dublin Report, 1908) that it is probable that the latter occurs close by. A few yards down-stream a very characteristic pink calcareous nodule was found among the drift pebbles of the bed of the Brook

The occurrence of the dark calcareous nodules and burrows or tracks further up-stream suggests a comparison of the beds there with those of Robin's Tump (see Sheffield and Portsmouth Reports, 1910, 1911).

Excavation No 47, Comley Brook

At about 40 yards south-south-east of No 13 (Dublin Report, 1908) a small excavation in the left slope of the valley disclosed brownish shale, with bands of hard ringing grit, dipping at about 45° to the south-west These rocks, which are in complete agreement with those found in Excavations No. 13 (Dublin Report, 1908) and No. 46 (above) I refer to the group Quarry Ridge Shales.

Excavation No. 49, Comley Brook, South-West Slope

At about 80 yards up-stream from the commencement of Excavation No 47 (above), there is a rocky shoulder the foot of which has been cut away to make room for a cart-track between it and the stream. The rock seen consisted of green sandstone, and on clearing away the soil and herbage a section was exposed which appears to be of special interest both from stratigraphical and palæontological points of view.

At first I found here several species belonging to the *Olenellus* (*Protolenus-Callavia* [1]) fauna, and then, apparently from the same material, a pygidium of a *Paradoxides* which may be referred to *P Hicksii* (Salter) or to one of its allies. On further study of the section it became evident that just at this point Lower Comley Sandstone, with some calcareous nodules (Lower Cambrian), and of the same horizon as that found at distance 9 to 10 yards on Excavation No 47 (see above, p. 138), has been broken up to form a breccia with but little addition of extraneous material, so that the matrix and the included blocks have very much the same lithological aspect

In the upper part of this ' Breccia Bed ' the matrix is somewhat calcareous and there are comparatively few included blocks. In the median portion of the bed the included sandstone and limestone blocks are very plentiful, and the original interstices between the blocks are filled up with a matrix of sand clearly derived from the disintegrated ruins or wash of the same materials as those of which the blocks are composed. At the base the bed consists of fractured sandstone with little, if any, matrix between the fragments. Below this the green sandstone seems to be intact, but is not fossiliferous

[1] Cobbold, *Q.J.G S.*, vol. lxvii., 1911, p. 297.

The fauna of the included blocks is clearly Lower Cambrian, and the same as that found in the *Olenellus*-Limestone of the Comley Quarry.

The matrix contains many species of a *Paradoxides* fauna which appears to be new to the district, and which, from the presence of *Conocoryphe æqualis* (Linnarsson) and a *Liostracus*, seems to indicate a higher horizon of the Middle Cambrian than that of the conglomeratic base of the Quarry Ridge Grits, which is in contact with the Lower Cambrian in the Comley Quarry and in Robin's Tump.

The finding of specimens of *Olenellus* (or rather of *Callavia*) and other members of the Lower Cambrian fauna in close contact with fragments of *Paradoxides* is no new thing in the district, for fossiliferous pebbles are not infrequent, both at the Quarry and at Robin's Tump, in the conglomeratic base of the Quarry Ridge Grits (Middle Cambrian), but in those places the distinction between matrix and included blocks is obvious, owing to the admixture of numerous rounded grains of quartz and other pre-existing rocks, while here, at Excavation No 49, the distinction could hardly have been made out without the presence of the fossils.

The section in descending order is as follows:—

(*a*) Grits and shale, of undetermined horizon —	Ft
(a_1) Hard ringing grit, top not seen . . .	2
(a_2) Brownish shale, much crushed . .	2
Probable fault	
(*b*) The Breccia bed	5
(*c*) Lower Comley Sandstone:—	
(c_1) Green sandstone, flaggy and reddish in places	3
(c_2) ,, ,, compact	4
(c_3) ,, ,, soft and much broken	4
(c_4) ,, ,, harder and more compact	3
(c_5) ,, ,, broken, base not seen	3

The dip is about 45° to the south-west

Up to the present fossils have only been found in the Breccia bed, they are given below in two lists—(A) those derived from the matrix, Middle Cambrian; (B) those derived from the included blocks, Lower Cambrian:—

(A)—From the Matrix

* *Paradoxides*, sp., *cf* *P. Hicksii* (Salter), and *P* *Sjogreni* (Linnarsson) (Pygidia and free cheeks)

* *P.*, sp, *cf. P. rugulosus* Corda (Glabella)

P, sp. indet, various fragments

Agraulos, *cf. A. quadrangularis* (Whitfield).

Conocoryphe bufo (Hicks).

C. æqualis (Linnarsson)

C *impressa* (Linnarsson).

Dorypyge, sp. nov, with a reticulate test.

Microdiscus punctatus (Salter)

Ptychoparia (*Liostracus*) sp. allied to *Pt* (*L*) *pulchella* (Cobbold).

Hyolithellus, sp., a large form, similar to that from the Quarry Ridge Grits

Kutorgina cingulata (Billings) ?

Acrothele, *cf. A. granulata* (Linnarsson), a fragment.

Linnarssonia (?)

* Since this report was written better specimens have been found, indicating a distinct species of *Paradoxides* intermediate between the three species here mentioned.

(B)—FROM THE INCLUDED BLOCKS

Callavia Callavei (Lapworth)
Micmacca (?) *ellipsocephaloides*, var *senior* (Cobbold).
,, ,, var *strenuelloides* (Cobbold).
Microdiscus, sp., cf *M Helena* (Walcott)
Ptychoparia (?) *attleborensis* (S and F)
Kutorgina cingulata (Billings)?
Linnarssonia, sp.
Lingulella, sp

There is often considerable difficulty in deciding whether any particular fossil belongs to the matrix or is part of an included block. As a rule the state of preservation is a guide. The *Paradoxides* and associated species generally occur as well-preserved casts of a red, yellow, or rusty colour, or, where the test is preserved, of a slaty grey, but sometimes they are whitish The fragments of *Callavia* and its associates often have a white egg-shell texture, exactly similar to those found in the *Olenellus*-Limestone of the Quarry, but they also occur as brown ferruginous casts

Excavation No 50, Comley Brook, South-west Slope

A little tributary hollow joins the course of the Brook just above Excavation No 49, and beyond it is another shoulder of rock almost entirely covered with herbage A trench about 18 yards long on this ground disclosed a thickness of about 20 feet of green sandstones with a dip of about 45° towards 20° south of west.

Some of the beds of sandstone are very soft, others are harder and flaggy, with white silky partings and indistinct tracks of organisms Notwithstanding the length of this trench the Breccia bed of No 49 was not encountered, and further elongation was impossible on account of the growing crop

I refer these beds to the Lower Comley Sandstone

Excavation No 51, Francis' Field

Several trials were made along the line of the western fence to Francis' Field near Excavation No. 27 (see map, Sheffield Report) One of these disclosed a thick band of rather coarse grit, with a dip of 45° towards 18° south of east The following is the full section in descending order.—

	Ft
(*a*) Brownish shales, with hard micaceous sandy bands, top not seen. Fossils, *Acrotreta*, sp , and an ostracod . . .	7
(*b*) Yellowish grit, with some small pebbles of quartz and some patches of dark brown rottenstone	7
(*c*) Brownish shale, base not seen	1

The easterly dip of these beds is so different from that shown in the Excavations Nos. 47 to 50, that it is evident that we have passed out of the region of Dairy Hill domical fold and have touched beds which are probably superior to those of the Hill House Ridge (Excavation No. 5, see Dublin Report, 1908).

Conclusion.

The discovery of fossils of the *Olenellus* fauna in the bedded green sandstones of Comley Brook is of interest in itself as proving the existence of Lower Cambrian strata *in situ* on the south-west side of the Dairy Hill dome, while the occurrence of the specimen, provisionally referred to Walcott's genus *Wanneria*, adds a new form to the Lower Cambrian fauna of Europe.

The Breccia bed of Excavation No 49 has a double interest. It affords new and confirmatory evidence of the break between the Lower and the Middle Cambrian of the Comley area, and the fauna of the matrix contains forms identical with certain Middle Cambrian species from Scandinavia and South Wales.

The whole story of the Cambrian rocks of Comley in so far as these rocks and their fossils are disclosed by the excavations carried out for the Committee cannot yet be written, but it may be of interest to note the principal results as they have appeared in my annual reports since 1908:—

1. *Excavations of* 1907, *reported to the Dublin Meeting of* 1908.

Discovery of a *Protolenus* fauna immediately above the fauna of the *Olenellus*-Limestone

Fixation of the local stratigraphical line of division between the Lower and the Middle Cambrian.

2. *Excavations of* 1908, *reported to the Winnipeg Meeting of* 1909.

Discovery of a higher Middle Cambrian fauna containing *Paradoxides Davidis* (Salter) succeeded above by shales with *Orthis (Orusia) lenticularis* (Wahlenberg), in the northern part of the area, near the Shoot Rough Road.

3 *Excavations of* 1909, *reported to the Sheffield Meeting of* 1910.

Additions to the *Paradoxides Davidis* fauna (*Billingsella*, *P rugulosus*, &c.).

Discovery of Lower Cambrian fossils in the southern part of the area near Robin's Tump, and of the exhibition there of the unconformity between the Middle and Lower Cambrian.

Publication of a diagram, showing the inter-relations of the Cambrian strata of Comley as far as then known.

4. *Excavations of* 1910, *reported to the Portsmouth Meeting of* 1911

Additional and confirmatory evidence of the unconformity at Robin's Tump.

Discovery of *O. lenticularis* shale to the south of the spot.

5. *Excavations of* 1911, *the subject of the present Report.*

Discovery of bedded green sandstone of Lower Cambrian age in Comley Brook, affording fossils characteristic of the *Olenellus*-Limestone of the Comley Quarry.

Discovery of a Middle Cambrian Breccia largely composed of the débris of the above-mentioned Lower Cambrian sandstone, but having a matrix affording a *Paradoxides* fauna, apparently new to the district.

Investigation of the Igneous and Associated Rocks of the Glensaul and Lough Nafooey Areas, Cos. Mayo and Galway.—Report of the Committee, consisting of Professor W. W. WATTS (*Chairman*), Professor S. H. REYNOLDS (*Secretary*), Mr. R. G. CARRUTHERS, *and* Mr. C. I. GARDINER.

THE district to the South of Lough Nafooey was visited during August 1912. In general the geological structure is the same as that of the Kilbride district to the East. There seems little doubt that the centre of eruption in Arenig times lay nearer to Kilbride than to Nafooey, for the Arenig lavas (spilites), which show excellent pillow structure, are far less intermingled with breccia near Lough Nafooey than they are at Kilbride. The lowest beds seen are ashes, breccias, and a conglomerate containing beds of black chert and shale. Limestone breccia has been found at two places amongst the ashes. Fossils from these beds are very scarce.

Succeeding these deposits comes a thick mass of spilite, containing in places felsite and spilite breccia.

All these Arenig rocks are pierced by felsite intrusions, but none of them are of any great extent.

On the North a pebbly quartzose grit and conglomerate (probably of Llandeilo age) rests on these Arenig rocks, while on the South they are overlain by Llandovery beds continuous with those of the Kilbride district to the East. These show the same succession of deposits as at Kilbride, and are covered, as they are there, with grits, which are of Wenlock age.

Just as at Kilbride, lime-bostonite and coarse porphyrite are intruded at the base of the Silurians. Dolerites, sometimes micaceous, are intruded into the Silurians and Arenigs, while felsite is intruded at the base of the (?) Llandeilo grits and into them as well.

Index Generum et Specierum Animalium.—Final Report of the Committee consisting of Dr. HENRY WOODWARD (*Chairman*), Dr. F. A. BATHER (*Secretary*), Dr. W. T. CALMAN, Dr. W. EVANS HOYLE, *the* Hon. WALTER ROTHSCHILD, Dr. P. L. SCLATER, *the* Rev. T. R. R. STEBBING, *and* Lord WALSINGHAM.

DURING the year 1911-12 work on this 'Index' has proceeded steadily, and a large number of volumes has passed through the hands of Mr. C. Davies Sherborn.

Huebner's entomological works have been thoroughly examined,

and the results of the researches of many workers have been embodied in a paper by Sherborn and Prout in the 'Annals and Magazine of Natural History' for January 1913. All the books of Fallén and Fabricius have been indexed, as also those of Fischer von Waldheim and John Fleming, with many others. Increased cabinet accommodation has been necessary, and this has been, as before, provided at the Natural History Museum by the Keeper of the Geological Department

As regards the continuation of the work, the Committee has great pleasure in reporting that the Trustees of the British Museum have included the compilation of the 'Index Animalium' in the General Library Service of the British Museum (Natural History). It has thus become an official undertaking, and Mr. Sherborn will rank as 'Special Assistant' on the staff. This is most gratifying to all parties concerned, for it ensures the safety and completion of the manuscripts which have accumulated during the past twenty-two years There are now some 664,000 slips, representing 332,000 entries in duplicate, and a great mass of manuscript notes on the dates of books which have passed or will pass through the compiler's hands Much of this has been printed separately or been included in the official catalogue of the libraries of the British Museum (Natural History)

All manuscripts and documents connected with the work have been handed over by the Committee to the Trustees of the British Museum for preservation in the Natural History Museum, where they may be seen, on application during official hours, by those interested

In making this final report the Committee desires to express its own and Mr Sherborn's sincere thanks, not only to the Trustees of the British Museum for their past and present help but also to those Societies that have from time to time aided the work with pecuniary grants—namely, the Royal Society and the Zoological Society of London. Above all, those thanks are due to the British Association for the consistent way in which it has supported the undertaking for the past twenty years, support which alone made possible the successful termination of the first part (1758-1800) The Association will doubtless join the Committee in renewing its thanks to the Syndics of the Cambridge University Press for their generosity in printing and publishing this part It was issued in October 1902 as a handsome octavo volume of 1,255 pages, containing 61,600 entries, at the price of 25s On the value of that volume to the zoologist there is no need to insist here; it has spoken for itself to everyone who has taken the trouble to consult it. The manuscript of the second part (1801-50) is well advanced and will now proceed safely towards completion under new auspices.

Your Committee cannot cease its connection with this important work without an expression of gratitude to Mr Davies Sherborn for his devoted labours in the past, and of confidence in his energy to carry to a conclusion the second part of the 'Index Animalium'

time, as extinction threatens only the large Rorquals (*Balænopteridæ*), Right whales (*Balænidæ*), and Sperm whales (*Physeteridæ*), which are regularly hunted.

The disadvantages arise entirely from the fact that the hunting and subsequent cutting-up of the whales have to be looked at simply from a commercial point of view by the whalers. In my own limited experience—and I believe in the experience of everyone who has visited a station with a view to scientific observation—the authorities of the company are quite willing to give every facility possible, but obviously the prosperity of the company must be the first consideration, and as this may be said to depend largely on the celerity with which the whale carcases are cut up and transferred to the boilers—every moment wasted being so much good oil lost, as it runs from the blubber and meat—the time necessary for careful observations and the prosperity of the company are incompatible. Again, the practice of pumping air into the dead whale to facilitate towing often results in the body bursting, on account of the internal accumulation of gases, sooner than it would in the absence of this blowing-up of the carcase. Lastly, the method of cutting up the body is not the one which a scientific observer would choose if he had the power so to do. In spite of all this there is a great advantage which must not be overlooked. The Whaling Company authorities will almost invariably allow an observer to go out on the whaling-boats, and this, after all, gives us practically the only means of observing these extraordinary mammals under natural conditions. A minor disadvantage, but one which cannot be entirely neglected, depends on the fact that the whaling stations are nearly always situated in places which are more or less difficult of access. These advantages and disadvantages have been noted by other observers,[1] but as they particularly impressed themselves upon me during my three months' stay at the Belmullet Station, I have thought them worth repeating.

The whaling season for 1911 at the Belmullet Station was fair from a commercial point of view. About 2,200 barrels[2] of oil were obtained, besides guano and whalebone, from sixty-three whales, giving an average of about thirty-six barrels per whale. This is a fairly good yield of oil, although the total number of the catch is not large. For the Northern Stations—that is, those off Iceland, the Shetlands, Ireland, &c.—thirty whales per boat is considered a minimum for a factory to keep working at a profit, but it must be noted that the yield of oil is not by any means proportional to the total number of the catch. A female with unborn young gives the best yield, whilst a female with a suckling probably yields the least. In the case of most of the Southern companies only the blubber is taken, this being stripped off and the boiling done on the steamer at sea. The carcase is turned adrift, and this is a great waste from a commercial

[1] *E.g.*, Lillie, *Proc. Zool. Soc.*, 1910, 2,769.

[2] One barrel = 200 kilos = 4 cwt. (approx.). Six barrels = 1 ton is a nearer approximation.

point of view, if from no other. The carcase represents rather more than one-third of the total value of an ordinary whale

Most of the whaling has been carried on to within a few years only in the Northern Hemisphere Recently, however, many stations have been opened in the South—*e g* , off South Africa—and large catches have been taken I was told of a station which, in the 1911 season, was taking twenty whales per day Most of the whales brought in at the Belmullet Station appear to be caught on or about a bank situated in a north-westerly direction. There is no doubt that the movements of whales, especially of the Mystacocetes, are largely due to the presence or absence of suitable food, and the bank mentioned above appears to be a regular feeding-ground for *Balænopteridæ* A greater knowledge of planktonic movements would no doubt go far to explain the presence or absence of the 'Finners' at given places at certain times The state of the weather appears to be an important factor A long spell of fine, calm weather appears to send the whales further out, whereas dull, cloudy, and rainy weather brings them in This is especially the case with the Mystacocetes, and is probably almost entirely due to the movements of the plankton on which these animals chiefly subsist The sperm whales (*Physeter macrocephalus*, L) are generally caught further off the land in deeper water, due no doubt to the food consisting almost entirely of deep-sea cephalopods

Before passing on to consider the observations and results of my stay at Belmullet, I must express my thanks to Professor J S Gardiner, F R S , who, as Secretary of the Committee, gave me the opportunity of undertaking the investigation, and who has since given me much valuable help and advice at Cambridge, where the detailed work has been done

During my stay in Ireland Mr R M Barrington, F L S , showed me great kindness, and helped me greatly by his local knowledge, and to him I express my hearty thanks I cannot express my obligations too highly to Mr D Bingham, of Bingham Castle, with whom I had the good fortune to stay during my visit, and whose help and advice on all occasions were freely given, and were invaluable I have also to thank Dr R F Scharff, of the Dublin Museum, for his kind offer of help

In my actual work at the station I can only say that it was the advice, information, and cordial help given by Captain Bruun, the manager of the Whaling Company, which made the work possible, and for these I thank him most sincerely, and I must extend my thanks to many friends at the whaling station In the more detailed work at Cambridge I have to express my indebtedness to Dr A E Shipley, F R S , Dr H Gadow, F R S , Dr H K Anderson, F R S , and Mr L A Borradaile, M A , for much help and advice on special points

II General Factory Procedure

Although whales were first hunted for their oil alone, even before the use of whalebone was known, there are now at least half a dozen

products of economic importance obtained from these animals A modern whaling station obtains

(a) Oil.
(b) Whalebone.
(c) Meat (Cattle food) } (Manure).
(d) Bones. }
(e) Glue.

Besides these there are two subsidiary products from the Sperm whale (*Physeter macrocephalus*, L)—viz , ambergris and sperm teeth The latter (sperm teeth) are now sold as such, and Captain Bruun informed me that he had found a market for them in 1911 for the first time There does not seem to be any reason why they should not be used for manufacturing articles in the same way as ordinary bones and ivory The trunk bones are far too porous and contain large quantities of oil

(a) *Oil* —This is still the most important product. To extract it, every part of the animal, with the exception of the whalebone and sperm teeth, is boiled for an average of about twenty-four hours When a whale is towed into the station it is anchored to a buoy until the men at the factory are ready to deal with it When all is ready, the animal, perhaps by this time enormously distended by the internal generation of gases, is brought to the bottom of the flensing-slip, a large chain is attached round the tail, connected to a steel-wire rope and the whale is slowly hauled up the inclined plane by a powerful steam winch The animal is drawn up rather on its side, but sometimes nearly on its back This is due to the fact that it floats in this position while in the water, the gases accumulating in the body cavity and distending the belly The flensing-plane has to be very strongly supported by piles on account of the great weight of the whales A 60-foot whale weighs something like 70 or 80 tons

The next process is to strip off the blubber 'blanket' This is performed by two Scandinavians called 'blubber-flensers' The work of these men consists entirely in stripping off the blubber and taking out the baleen The knives used are of a special kind (fig 1) The blubber is cut through along the mid-dorsal and mid-ventral lines of the animal, and two cuts are also made along each side Thus there are marked out the three strips which are taken off from each side of the whale A chain fastened to a steel-wire rope is attached to the head end of each of these strips, and the blubber taken off from the head end towards the tail by the help of a steam winch, the flensers using their knives to ensure the strips coming off cleanly, with as little meat as possible.

The blubber is then cut up into manageable blocks by some of the unskilled local workers, and finally the blocks are fed into a arrangement of a revolving circular knife and an elevator fixed on the flensing-slip The blubber is thus transferred in fairly small pieces into the boilers as soon as removed from the whale. After the blubber has been entirely removed, another Scandinavian, called the 'meat-flenser,' cuts off the head, which is chopped up separately. The carcase, from which the viscera have been removed, is then handed over to this

meat-flenser, who strips the meat from the bones, the whole of the meat being taken off in four strips—two on each side. The ventral strip on each side consists of the meat overlying the ribs, and the dorsal strip of the main layer of meat lying along the vertebræ. Finally the meat-flenser cuts up the backbone, separating the vertebræ very neatly. The whole of the meat and bones in pieces of workable size is raised by elevators and tipped into boilers.

With regard to the boilers, the blubber-boilers are open, but those in which the meat and bones are put are closed, so that in the latter

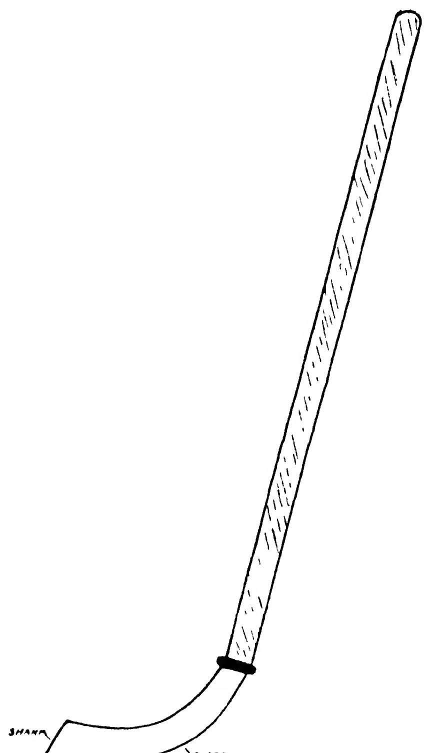


Fig. 1.—Flensing Knife (approx. $\frac{1}{12}$ nat. size).

the pressure of the steam helps to extract the oil, which is relatively less plentiful in the meat and bones than in the blubber. A diagrammatic sketch of a blubber-boiler is shown in fig. 2.

The blubber is given three successive boilings, the duration of which varies, the average being about eight hours each. After each boiling the contents of the boiler are allowed to settle, and the oil is run off into vats. On the third boiling the boiler is closed at the top and the steam allowed to press the contents to ensure all the oil being extracted. Finally all the fat disappears and only the dark-coloured

integument is left as a black mud. To illustrate the modern no-waste methods used at the factory, it may be mentioned that one man does nothing but collect the oil, blood, &c., which runs from the animals as they are being cut up, and boil these scrapings in small, open-air

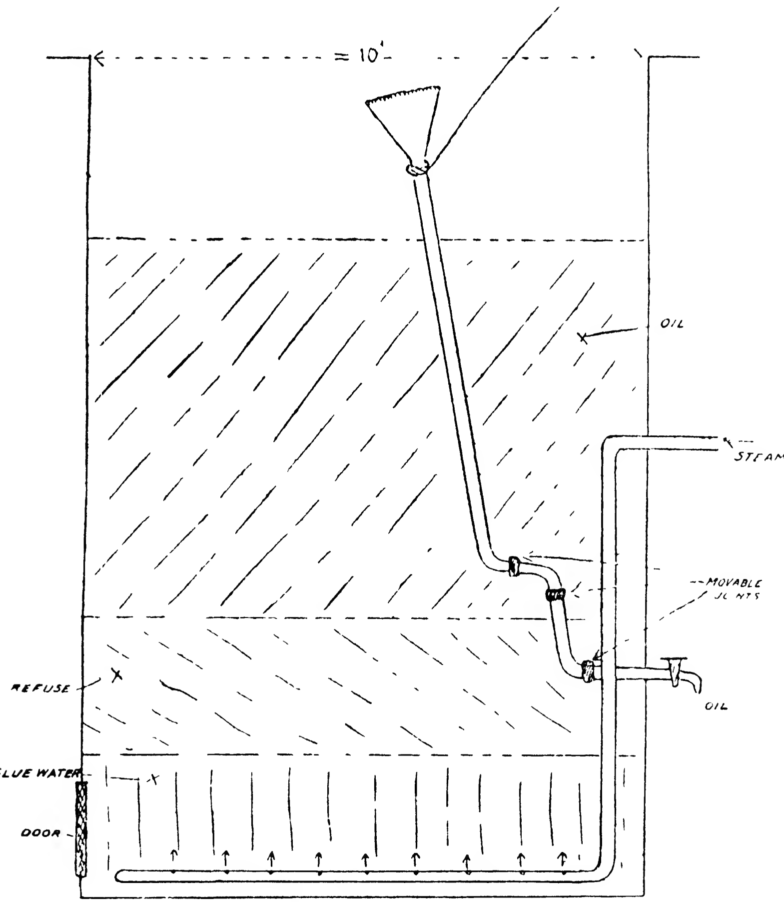


FIG. 2.—Blubber Boiler.

boilers. During the 1911 season two hundred barrels of No. 4 oil, worth about 600*l.*, were obtained by this method alone.

The kinds of oil obtained are arranged according to quality, thus:—

i. Spermaceti (from the head of the Sperm whale).
ii. Sperm blubber-oil.
iii. No. 1 (from the blubber of Fin whales).
iv. No. 2 (from the blubber of Fin-whales on second boiling).
v. No. 3 (from meat and blubber in a closed boiler).
vi. No. 4 (from the bones, trimmings, and sperm meat).

Most of the oil goes to Glasgow, where much is sold to manufacturers of explosives for the purpose of extracting the glycerine.

The market price of the oil fluctuates In the 1911 season it was about 23*l*. per ton This applies to the ordinary oil as put into the barrels, which consists of Nos 1, 2, 3, and 4 mixed. Spermaceti and sperm blubber-oil fetch about 10*l* per ton more

The following represent the rough average yields for four of the commoner species of whale captured:—

	Barrels
1. Rudolphi's Rorqual, Sejhval (*Balænoptera borealis*, Lesson)	about 10
2. Common Fin-whale (*Balænoptera musculus*, Linn.) . .	15–70
3 Blue Whale (*Balænoptera sibbaldii*, Gray) . .	50–70
4. Sperm Whale (*Physeter macrocephalus*, Linn.)	65–80

(*b*) *Whalebone* —The treatment of the whalebone is comparatively simple The plates are separated, scrubbed and soaked in warm soda solution, washed in warm water, and finally spread out in the open air to dry When dry the plates are packed in sacks As regards the baleen from Fin-whales, there are about fourteen sacks to the ton The price obtained for this in the 1911 season was 45*l* per ton, and 6 to 7 tons were obtained during the season Much of the whalebone goes to Paris, where, I believe, quite a considerable quantity is used in the form of fine threads woven into silken fabrics in order to make the latter stiff

(*c*) *Meat and bones* —The residue from the meat and bones, after prolonged boiling until no more oil can be obtained, is dried in a large cylinder, which is heated and made to revolve about its axis The dried products—*i e* , from the meat and from the bones—are then ground in a mill and finally packed in sacks The meat in this stage has a comparatively pleasant smell, and looks very much like coarsely ground coffee The dried and ground meat alone is used as cattle-food in Norway, and a mixture consisting of two parts of ground meat to one part of ground bone is used as guano

From the first twelve whales caught in the 1911 season 345 bags[1] of guano were obtained These products are sent to Norway

The meat of most of the Balænopteridæ, when taken fresh, can be eaten, and is very palatable, as I can testify by experience in the case of meat from *Balænoptera musculus* (L), the common Finner

(*d*) *Glue* —The water produced by the condensation of steam in the boilers was formerly run back into the sea That there is plenty of gluey substance in this water is shown by the fact that if two pieces of wood be moistened with it and allowed to remain pressed together they are found to be firmly attached when dry The glue is particularly plentiful in the dark skin situated between the epidermis and the blubber This, in the form of the black mud mentioned above, was formerly thrown away Different processes have been tried to extract the glue, but without much success The great difficulty appears to be to get the product to settle At the end of the 1911 season a new triple evaporator was installed at the Belmullet Station, and promises to be more successful

[1] One bag = 2 cwt (approx).

Whaling-boats.—These are somewhere about 100 feet long, and are capable of attaining a speed of about 10 knots per hour. To enable them to turn quickly while chasing, many have perforated keels. There is a crow's-nest placed high on the forward mast. It has been the custom to paint the bottoms of the boats a green colour, the idea being that the hull would be made less visible to the whales, and so less likely to frighten them.

Captain Bruun thinks, however, that it makes no difference in chasing the whales, and he now uses the ordinary red-lead paint.

The *harpoon gun* is mounted high in the bows of the ship, and is arranged on a swivel, so that it can be moved easily and quickly in any direction round the bows. The *harpoon* is shown diagrammatically in fig. 3. It is about 4 feet long over all. There is a conical tip with

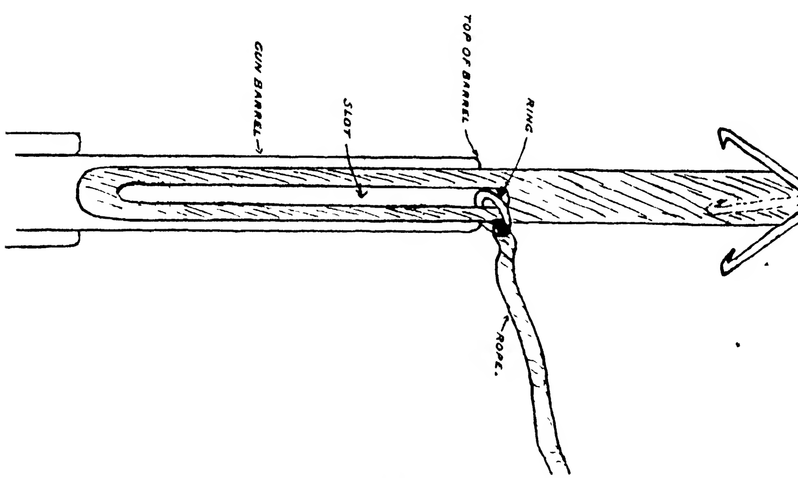


FIG. 3.—Harpoon (in gun) (approx. $\frac{1}{11}$ nat. size).

three movable hooked barbs, and an arrangement by which an explosive shell is attached, the shell exploding inside the body of the whale.

The harpoon is attached to a strong 3-inch hempen rope, which is run round a winch on deck and then over a pulley arrangement attached to the foremast, the further end of the rope being fastened to a long, strong spring fixed along the bottom of the boat. This latter is to prevent any great amount of jarring when the rope is run out.

The fin-whales, when dead, generally sink, except they be very fat. They are hauled up from the bottom, a pipe is thrust into the body cavity, and air is pumped in, the hole being afterwards plugged. The whales are towed tail foremost, generally alongside the boat, but in rough weather they are towed astern. The tail-flukes are cut off immediately on capture, to lessen the resistance to towing.

The harpoons are not fired at a longer range than about 50 yards, so that great skill is required in manœuvring the ship. An attempt is made to shoot just as the whale begins to dive downwards, and to hit, if possible, just behind the shoulder.

III. Questions of General Biology.

1. *The extinction of the larger Cetacea.*—In view of the large numbers of the largest kinds of Cetacea which are now killed every year, the question of their probable extinction in the course of comparatively few years must be seriously considered. The case of Steller's Sea-cow (*Rhytina*) is a well-known example of extinction produced by excessive hunting in recent times. With a view to preventing this possible extinction there is some discussion as to legislation in Norway and England. It is suggested that there should be a closed season for the Northern Whale 'Fisheries' as in the Seal 'Fisheries.' The serious point is that so many gravid females are killed, and it is impossible for the whalers to identify a gravid female, as such, while she is swimming in the water. Naturally, the proposed limitation of the whale-hunting does not meet with the approval of the whalers. According to them the whaling in the Northern stations will cease automatically *before* the extinction takes place. As mentioned above, a minimum catch of about thirty whales per steamer in the Northern stations is necessary for a factory to keep working at a profit. Thus, when this minimum has been passed, the whaling station closes down automatically. It is said that this will take place before the total extinction of the species on account of the minimum catch being comparatively high.

The underlying idea seems to be that of a definite number of whales passing over a given area at one time, only a certain percentage are ever caught, on account of the difficulty in locating the animals and the chances of the chase. As the total number of animals passing over a given area becomes fewer, the percentage actually caught will fall. The conclusion drawn is that this fall will cause the minimum catch per boat to be reached before the total extinction takes place. How far this reasoning is sound is doubtful, but I give it as it was given to me.

The actual reduction in the number of the whales has been less than it might have been because the whalers only kill the larger individuals, *i.e.*, those over about 40 feet, as noted above.

In the southern hemisphere there are large numbers of whales, which have been extensively hunted only within quite recent times. Against this must be put the fact that the minimum catch per boat is about three times what it is for the northern stations, on account of the greater expenses for transportation, &c., so that the question of ultimate extinction will probably soon have to be considered for this region also.

2. *Migration and line of movement.*—Many whales manage to keep an almost absolutely straight course, as if steering by a compass. How is this done? If their sight be good enough, it is possible that they steer by landmarks on the bottom, but they could only see these when diving. The Right whale (*Balæna*) especially appears to have this definite line of movement, and it is said to keep near the shore while passing the Irish coast. If it be guiding itself by landmarks on the sea-bottom, it would be easier to do this in shallow water. If a whale be chased out of its course, and then left alone, the whalers say that it returns to

exactly the same direction of progression as originally This may happen in deep water, where it would be practically impossible for the whale to dive deeply enough to see the sea-bottom for guidance. It would appear that whales have a definite sense of direction and location When whales are observed constantly moving in a certain direction, the question arises—what is the object of this movement? It may be a certain feeding-ground, or perhaps a definite spot for breeding. There may be definite migration [4] over long distances for these purposes. Two instances of this were given me by Capt Bruun A few years ago a 'school' of Humpbacks (*Megaptera longimana*, Rud) regularly came from the White Sea across to the north of Norway every year in the autumn, about October They passed Norway and made their way to Iceland, where the females bore young in the following spring Apparently most of these whales have now been killed

In California there are long inlets with fairly narrow mouths In the autumn 'schools' of gravid female Humpbacks swim into these inlets The young are born, and in the following spring the bull whales come, apparently to fetch the females and young

There seems to be a more or less definite periodicity in the appearance of certain species of whales Thus the whalers say that the Right whales (*Balæna biscayensis*, Grav) follow the Sejhvals (*Balænoptera borealis*, Lesson), and both disappear by the end of June The last Sejhval caught from the Belmullet station in 1911 was brought in on May 18, but most of the first half of June was too stormy for 'fishing'

Almost all the whales passing the coast of the West of Ireland during the summer appear to be moving north Some of the whaling stations further north had bad catches on the whole in 1911 There were three stations shut down in Iceland One of these only obtained ninety whales with nine steamers

It is possible that most of the stations on and just off the West of Europe 'fish' from the same batches of whales which come up from the south and move northwards gradually through the summer Thus by the time a 'school' reaches the more northerly stations its number will be diminished, and the remaining individuals may be more wary

Mr R C Haldane [5] states that the whales (especially *Balænoptera musculus*, the common Finner) are not getting fewer at the Scotch stations This may point to the conclusion that the whales passing the West Coast of Ireland move directly towards Iceland, and may not form the same 'schools' which are hunted from the Shetland stations

All the whalers believe that the whales live in separate 'schools' Captain Bruun does not think that whales ever cross the Line In the case of whales living fairly near the Line there appears to be nothing to prevent them crossing it in their long-distance movements. However, during the summer the migrating movements lead almost invariably from warmer to colder seas, so that whales living south of the Line would naturally move southwards towards the South Polar seas

3 *Diving and 'blowing'* [6]—The phenomenon of 'blowing' is very

[4] Vide T Southwell, 'The Migration of the Right Whale,' *Nat Science*, vol xii, No 76, June 1898.

[5] Haldane, *Ann Scot Nat Hist*, January 1907 and 1910

[6] Vide E G Racovitza, *Rept Smithsonian Inst*, 1903, p 627.

characteristic of the Cetacea. The duration and manner of effecting this are very definite, according to the whalers, and are different for different kinds of whales. Thus it is said that the common 'Finners' (*Balænoptera musculus*, *L.*) continually ascend and descend with an almost undulatory motion. Blue whales (*Balænoptera sibbaldii*, Gray), on the other hand, behave somewhat differently. They appear at the surface, give a definite number of blows or spouts, and then dive, apparently fairly deeply. They then remain submerged for a definite time. The time of submergence and the number of expirations on rising to the surface appear to be directly proportional to one another. Thus, if a submergence of 10 minutes is followed by six expirations, a dive of 5 minutes' duration will be followed by three 'blows.' It is said that the phenomenon may be accurately timed by a watch.

Of course the great regularity is only found when the whales are progressing normally and are not being chased. With regard to the possible duration of submergence, the whalers believe that whales can remain under water for a comparatively long period if they wish.

Sometimes, when plenty of whales can be seen at one place, they will disappear for perhaps twelve hours, and then all appear again. Where do they go? It is certainly very questionable whether they can possibly be submerged all the time. The 'reappearance' may merely show the presence of another 'school' altogether, though the whalers do not seem at all certain about this.

I was informed that Sperm whales (*Physeter macrocephalus*, *L.*) normally remain under water longer than do the 'Finners.' In one case a Sperm whale was said to remain submerged for 55 minutes. It then came to the surface, gave one long blast, and then shorter and shorter expirations until it lay on the surface just breathing quietly.

As regards the depth of the diving, there seems to be no reason why the 'Finners,' which feed on organisms living near the surface, should require to swim down to any great depth, as apparently the only object in diving must be for food. In the case of the Sperm whales, which subsist almost entirely on large cephalopods, a greater depth of dive would be necessary in order to reach the bottom-living prey. This is confirmed by what has been said above regarding the duration of submergence, and it should be noted that the Sperm whales are generally found in deeper water.

In the South in calm weather many Humpbacks (*Megaptera longimana*, Rud.) are often found apparently asleep, breathing quietly on the surface.

4. *Rate of breeding.*—This is not known with any certainty. The periods of gestation are probably from about ten months to over a year. For *Balænoptera musculus* (L.) the period is generally supposed to be about eleven months,[7] and for *B. sibbaldii* from eighteen to twenty months (Guldberg). Breeding appears generally to take place once a year, but it is said that in the case of *Balænoptera sibbaldii* (Gray) it is only once in three years. There is almost invariably only one at a birth, a twin being very rare among the larger Cetacea. No such case occurred during the 1911 season at the Belmullet station.

[7] Haldane, *Ann. Scot. Nat. Hist.*, April 1905.

The actual time of pairing must vary considerably, as the size of the fœtus at a given time varies. This can be seen in Table XI., showing the *B. musculus* fœtuses measured by me. It seems probable that pairing takes place during the summer, and that the young are born in the winter or early spring months.[8] The young when born are said to be from a quarter to a third the length of the mother. A whaler told me of a fœtus of *B. sibbaldii* (Gray), 19 feet long which was seen by him. He considered that this was very near its time of birth. It is agreed that after birth the young grow quickly. There was a suckling estimated at 50 feet long with the female Blue whale (*B. sibbaldii*, Gray) labelled No. 2 in Table III. A suckling of this length is supposed to be not more than a year old, and it is said to remain with the mother for about a year.

5. *Probable varieties of the common 'Finner.'*—The Norwegians believe that there are at least two varieties of the ordinary 'Finner' (*Balænoptera musculus*, L.). Slightly differing accounts have been given as to the exact differences between the varieties, but the fact that there *are* variations as regards colour appears to be firmly established. Thus, Haldane[9] was informed that there were three varieties—large brown, dark grey, and smaller black. Lydekker[10] gives the varieties as darker, lighter, and yellowish. There is also the 'Bastard whale' of Cocks, which is supposed to be a cross between *Balænoptera musculus* (L.), and *Balænoptera sibbaldii* (Gray). Southwell[11] says that this is larger than the type of the former species, and that it has grey on the under-surface. The anterior baleen-plates are white and the remaining portions darker than usual. Undue importance must not be given to colour differences alone. It is well known that after death the intensity of the colour alters if the body has been exposed for any length of time, and no doubt many colour descriptions have been taken from individuals which have been dead for some time. However, it appears certain that differences are found commonly among individuals of *Balænoptera musculus* (L.), *B. sibbaldii*[12] (Gray), and *Megaptera longimana*[13] (Rud.). The variations may be due to age, or may be merely natural variations depending perhaps on the nature of the sea in which the animals live. The differences given by the Norwegians are generally colour differences alone, but Lydekker[14] states that the varieties may also be distinguished by their food.

I elicited the following information on this question of varieties. There are two distinct kinds of ordinary 'Finners' (other than the Bastard whale apparently). A smaller variety is of the usual dark blue-grey colour on the upper parts of the body, and is fairly hard to capture, showing an amount of cunning comparable with that of the Sejhval (*Balænoptera borealis*, Lesson) and of the Humpback (*Megaptera longimana*, Rud.).

[8] Vide the cases of Humpbacks in Iceland and California, above.
[9] Haldane, *Ann. Scot. Nat. Hist.*, April 1908.
[10] Lydekker, *Proc. Zool. Soc.*, 1911.
[11] T. Southwell, *Ann. Mag. Nat. Hist.*, vol. xvi., October 1905.
[12] Haldane, *op. cit.*
[13] Haldane, *Ann. Scot. Nat. Hist.*, April 1905.
[14] Lydekker, *op. cit.*

Larger forms are also met with, having a much lighter coloration on the dorsal surface, often with a yellowish tinge These are not so cunning in their habits, and are more easily caught, being more like Sperm whales (*Physeter macrocephalus*, L) in their slower movements. The smaller form appears to be the 'Herring whale' of the whalers, and to correspond to the smaller black (?) variety of Haldane Lydekker concludes that the dark Rorquals are probably the oldest, and that they feed on herrings and pilchards It must be noted, however, that he takes a variation in colour on the *under*-side of the tail for the differing colour character Also one would hardly expect the oldest animals to be the smallest, although Haldane's darkest variety is stated to be the smallest.

Evidently this question of varieties is not settled, and further reliable information must be obtained It seems to be certain that there *are* variations in colour, habits, and food, but whether the varieties can be given even sub-specific rank remains doubtful Although a *species* may be cosmopolitan, it does not necessarily follow that the *individuals* range over the whole world, and there seems to be no reason why more or less localised *races* should not arise [15] In the present state of our knowledge the facts certainly point to the existence of one or two of these races in the case of *Balænoptera musculus* (L), differing in several points from the type of the species

6 Opinions appear to differ with regard to the proportion in which the sexes of *B musculus* occur Thus Haldane [16] states that the cows are less numerous than the bulls Southwell [17] says that the sexes occur in about equal proportions, while True concludes [18] that the females predominate

The actual proportion in which the sexes occur certainly varies; thus, in the season of 1906 the Shetland whalers actually found the cows to be more numerous than the bulls,[19] although in other seasons the reverse had obtained If reference be made to Table II in this report it will be seen that the proportions are twenty-five males to twenty-one females From Table XI , however, it appears that the female and male fœtuses occurred in the proportion of five to two. Although the number of fœtuses is not very large, this would appear to indicate that the usual smaller number of large females captured is due probably to their greater timidity If a large number of fœtuses be used for this calculation it is found that the average shows that the two sexes occur in equal proportions,[20] so that the greater timidity of the cow appears to be the only explanation of the relatively smaller numbers caught in European waters

With regard to *B sibbaldii* all the adults I examined were females, but as the number amounted only to four, no conclusions could be drawn as to the proportions of the sexes

[15] Vide True, *Smithsonian Contrib. to Knowledge*, vol xxxiii , 1904, Introduction, &c

[16] Haldane, *Ann Scot Nat Hist* , April 1905, also April 1908

[17] Southwell, *Ann. Mag. Nat. Hist.*, vol. xvi., October 1905

[18] True, *op. cit* , p 112.

[19] Haldane, *Ann Scot Nat Hist* , January 1907.

[20] Haldane, *Ann Scot. Nat Hist* , April 1908.

THE SPECIES CAPTURED AT BELMULLET

The total catch at this station during the 1911 season consisted of 63 individuals. Before my arrival 12 had been caught, so that I had the opportunity of examining 51 specimens Each of these was examined to a greater or less extent. It was rather unfortunate that the whole of these 51 individuals was made up of two species only, viz., *Balænoptera musculus* (L),[21] the common 'Finner,' and *Balænoptera sibbaldii* (Gray),[22] the Blue whale There were 4 Blue whales, and the rest were common 'Finners' Of the dozen which had been captured in the earlier part of the season, 2 were Sejhvals (*Balænoptera borealis*, Lesson),[23] both of which were caught in the first half of May. There were also 2 Sperm whales (*Physeter macrocephalus*, L)[24] both captured on May 20. The rest consisted of common 'Finners' It will be noticed that no Right whales (*Balæna biscayensis*, Gray)[25] were taken in the 1911 season Also no Humpbacks (*Megaptera longimana*, Rud)[26] were taken, though several were seen during the season The first 'Finner' was captured on May 13, and this species was continually taken all through the season up to the end of September The first Blue whale was taken on May 30, and the last on August 11

The Right whales and Sejhvals are said to appear only during the earlier part of the season—in May and perhaps the early part of June

It must be noted that no Sejhvals were taken after the arrival of the Blue whales This is said always to be the case, the latter species following the former Other species [27] are seen off the coast of Ireland, but are too small to be worth chasing by the whalers

V MEASUREMENTS

A definite and, whenever possible, complete set of measurements was taken of every whale examined It was found impracticable to obtain the distance between the tips of the tail-flukes as intended, as most of the flukes were cut off directly the whale was captured, to reduce the resistance when towing into the station. Corresponding measurements were taken as nearly as possible in exactly the same way, but the weight of the animal distorts the shape of the body when on the flensing-slip, so that exact correspondence could not always be obtained in some measurements All the measurements are given in English feet and inches Where these have been obtained from Norwegian measurements, one Norwegian foot was taken as equivalent to 12½ English inches The measurements have also been reduced to percentages of the total length This method was adopted by True,

[21] Also called *B physalus* (Fabricius), *B rorqual* (Lacepède), *Physalus antiquorum* (Gray)

[22] Syn. *B latirostris* (Flower).

[23] Syn *B rostrata* (Rud.), *B laticeps* (Gray).

[24] Syn *P catodon* (Fabricius), *P. gibbosus* (Schreber), *P trumpo* (Gerard), and others

[25] Syn *B australis* (Desmoulins), *B eubalæna* (Flower), and many others

[26] Syn *Balæna hoops* (Fabricius), &c , &c.

[27] E g , *Balænoptera rostrata* (Gray)

and facilitates comparison with measurements taken in other units The station authorities record the total length of the whales captured, so that the lengths of those taken before my arrival were obtained and incorporated with those taken during the rest of the season. The sex of the individuals is not recorded at the station.

A. *Total Length*

1 *Balænoptera musculus* (L.), the Common 'Finner'—For this measurement the distance between the tip of the upper jaw and the notch of the flukes, measured along the back, was taken This is certainly the most convenient method, and the lengths so obtained may be compared without serious error with those taken by the whaling-station authorities, and also with lengths obtained from stranded specimens.

Table I shows the total length, date of capture, and, in the majority, the sex of the different individuals of this species captured in the 1911 season The first seven captures took place before my arrival at the station, and this accounts for the sexes being unknown It will be seen that the majority of captures took place in July and August

TABLE I.—*Balænoptera musculus* (L.).

Capture Number	Date of Capture	Sex	Total Length Ft.	in.	Capture Number	Date of Capture	Sex	Total Length Ft.	in.
1	May 13	?	51	6	28	July 26	♀	59	0
2	,, 16	?	64	0	29	,, 26	♂	68	9
3	,, 22	?	72	0	30	,, 31	♂	62	0
4	,, 22	?	43	0	31	,, 31	♂	67	0
5	,, 29	?	57	6	32	Aug 7	♂	63	0
6	June 11	?	72	0	33	,, 7	♀	75	0
7	,, 13	?	70	6	34	,, 11	♂	64	6
8	,, 29	♂	65	0	35	,, 11	♂	60	0
9	,, 29	♀	67	0	36	,, 12	♂	61	6
10	July 3	♀	60	6	37	,, 11	♀	66	0
11	,, 11	♀	67	3	38	,, 12	♂	64	6
12	,, 11	♂	53	3	39	,, 13	♂	64	7
13	,, 12	♂	55	3	40	,, 14	♂	62	6
14	,, 12	♀	70	9	41	,, 17	♂	62	6
15	,, 12	♀	54	3	42	,, 17	♀	66	8
16	,, 16	♀	74	9	43	,, 19	♂	65	8
17	,, 19	♂	65	7	44	,, 19	♂	59	5
18	,, 20	♀	65	7	45	,, 22	♀	67	8½
19	,, 20	♂	59	6	46	,, 22	♀	60	9
20	,, 20	♀	59	6	47	,, 23	♂	65	7
21	,, 24	♂	61	6	48	Sept. 5	♀	59	4
22	,, 24	♂	60	6	49	,, 10	♀	68	9
23	,, 24	♀	57	3	50	,, 12	♀	56	9
24	,, 24	♀	57	3	51	,, 18	♀	67	8
25	,, 24	♀	66	8	52	,, 18	♂	58	4
26	,, 26	♂	63	0	53	,, 18	♂	64	7
27	,, 26	♂	63	6					

Table II shows averages, total numbers, maxima, and minima collected together

TABLE II.—*Balænoptera musculus* (L.).

Average for all Specimens of both Sexes		Average for all Females		Average for all Males		Average for Mature Females	
No.	Length	No.	Length	No.	Length	No.	Length
	Ft. in.		Ft. in.		Ft. in.		Ft. in.
53	63 0	21	64 3	25	62 5	20	64 8

Average for Mature Males		Maximum for Females	Maximum for Males	Minimum for Females	Minimum for Males
No.	Length	Length	Length	Length	Length
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
23	63 2	75 0	68 9	54 3	53 3
		(72 ft., sex unknown)		(51 ft. 6 in. and 43 ft., sex unknown)	

Cocks's observations at the Norwegian whaling stations give an average length of 63 feet $5\frac{1}{2}$ inches for all specimens of both sexes. This is obtained from 186 individuals. The corresponding figure given in Table II., viz., 63 feet obtained from 53 individuals, agrees very closely with this. It must be remembered that the whalers do not attempt to capture any whale under 40 feet in length. The average total length for this species as captured in Newfoundland waters in 1899, 1900, and 1901 collected by True[28] is 59 feet $1\frac{7}{10}$ inch, considerably less than either of the figures given above.

As regards the average for all females, Cocks gives 64 feet $1\frac{1}{2}$ inch, deduced from 105 Norwegian captures. This again compares very closely with the corresponding figure in Table II., viz., 64 feet 3 inches. The figure obtained by True from 15 Newfoundland captures is 62 feet $3\frac{1}{2}$ inches,[29] which is also smaller than for European specimens. We find exactly the same thing when we consider the males. Cocks gives 62 feet 7 inches as the average from 81 captures, the figure in Table II. being 62 feet 5 inches, and the corresponding measurement for Newfoundland being 57 feet $1\frac{7}{10}$ inches (True). True gives 65 feet and 70 feet 8 inches as the maxima for Newfoundland males and females respectively.

These are both well below the corresponding figures in Table II., bearing out True's conclusion that the European *Balænoptera musculus* appears to be larger than the individuals from Newfoundland waters.

For the corresponding minima True gives 53 feet 9 inches and 50 feet 7 inches for Newfoundland males and females respectively. In this case the minimum given for males in Table II. is smaller than True's figure. We cannot draw any conclusion from this, however, as individuals of this length are certainly immature.

In deducing the average lengths for *mature* males and females I have followed True in taking Cocks's figure of 55 feet 7 inches as representing the minimum for mature individuals of both sexes. The

[28] True, *Smithsonian Contrib. to Knowledge*, vol. xxxiii., 1904, p. 115.
[29] True, *op. cit.*, p. 115.

figures given in Table II, viz, 64 feet 8 inches and 63 feet 2 inches for mature females and males respectively, compared with True's corresponding figures, viz, 63 feet 10 inches and 60 feet 5 inches for Newfoundland specimens, again show that the latter are shorter on the average than European individuals

With regard to the differences between the averages and maxima for Newfoundland and European specimens, True concludes that there are no sufficient grounds for doubting 'the specific identity of the "Common Finback" of the eastern and western Atlantic'

Although the *species* is almost certainly the same on both sides of the Atlantic, there is no reason to suppose that the *individuals* range over both eastern and western sides [30] As these whales travel in 'schools' or herds, there is no reason why the average lengths in different 'schools' should not be different, and it has not been proved that the 'schools' of the east and west mix, the general movements being north and south

2 *Balænoptera sibbaldii* (Gray), the Blue Whale —Table III is constructed for this species in the same way as Table I for the common 'Finner' One individual was captured before my arrival, so that its sex is not recorded The table shows that this species is captured all through the season It will be noticed that all four specimens examined by me were females

TABLE III.—*Balænoptera sibbaldii* (Gray).

Capture Number	Date of Capture	Sex	Total Length
			Ft. in.
1	May 30	?	71 0
2	July 14	♀	83 0
3	,, 15	♀	84 0
4	,, 18	♀	64 6
5	Aug 11	♀	70 0

Table IV corresponds for this species to Table II. The number of individuals is very small, so that the averages are not so trustworthy as those obtained from Table II

TABLE IV.—*Balænoptera sibbaldii* (Gray).

Average for all Specimens of both Sexes		Average for all Females		Average for Mature Females		Maximum for Females	Minimum for Females
No	Length	No	Length	No	Length	Length	Length
	Ft. in.		Ft. in.		Ft. in.	Ft.	Ft. in.
5	74 6	4	75 4	2	83 6	84	64 6

From seventy-two individuals Cocks obtained an average of 74 feet 10 inches for all individuals of both sexes from Norwegian stations. This agrees very closely with the figure given in Table IV, viz., 74 feet 6 inches. The corresponding average given by True for

[30] Vide above, iii, 5. Probable varieties of common Finner.

American specimens is 71 feet 7 inches For all females Cocks gives an average of 75 feet 8 inches, which again agrees very closely with the figure in the table. True gives a corresponding measurement of 70 feet.

The maximum length for females in Table IV is also larger than True's corresponding measurement, and agrees with Cocks's figure.

Following True in taking 72 feet as the minimum for mature specimens, we find that Cocks gives 79 feet 3 inches, True 74 feet 8½ inches, and Table IV. 83 feet 6 inches, as the average for mature females The figure from the table is not sufficiently trustworthy to be taken as exact, as it is deduced from only two individuals, but it shows that, as for the general average and maximum, the figures obtained from European specimens are larger than those from Newfoundland catches

This is a similar result to that obtained for *B musculus*, and similar conclusions may be drawn, though it is hard to see why in *both* species the larger individuals should be on this side of the Atlantic

The differences can hardly be due to a difference in the system of measuring, as the figures in Tables I. to IV. were obtained in the same way as True's

B. *Proportions*

1 *Balænoptera musculus* (L)—Table V shows a series of twelve measurements besides the total length As many as possible of this series were taken on every whale examined The actual measurements are those which are most useful in comparing with the results of other observers, and it is much to be desired that the series should be taken by any observer who is in a position to do so

All the distances are those which give the most definite points for measuring purposes, with the probable exception of the distances taken for the length of the pectoral fin The ideal measurement for this is from the tip to the head of the humerus, but it was found that if the flipper be arranged as nearly at right angles to the body as possible the posterior and anterior insertions gave fairly definite points

As mentioned above, the distance between the tips of the tail-flukes could not be obtained at the station, as the flukes were cut off Table VI shows the same measurements reduced to percentages of the total length in the case of each specimen The individuals are arranged in order of total length, the longest being first

Leaving out all immature specimens, *i.e.*, those below 55 feet 7 inches, Table VII. represents the average percentages for different dimensions in European (Irish) and American specimens respectively, the figures for the American individuals being taken from True [31]

From this table we get the somewhat curious result that all the proportions of the Irish specimens are a little smaller than those of the American individuals, although, as was shown above, the average total length of the latter is less than that of the former.

It will be seen that, other things being equal, the averages from the Irish specimens should be the more trustworthy, as a much larger number of individuals is considered

[31] True, *op. cit.*, p. 118.

TABLE V.—*Balænoptera musculus* (L.).

Measurement	No 8 ♂		No 9 ♀		No 10 ♀		No 11 ♀		No 12 ♂		No 13 ♂		No 14 ♀		No 15 ♀		No 16 ♀		No 17 ♂		No 18 ♀	
	Ft	in.	Ft.	in.	Ft	in	Ft.	in	Ft	in.	Ft	in.	Ft.	in	Ft.	in.	Ft.	in.	Ft	in.	Ft.	in.
Total length	65	0	67	0	60	6	67	3	53	3	55	3	70	9	54	3	74	9	65	7	65	7
Tip of snout to centre of eye	13	0	13	0	—		12	9	9	9	10	5	13	10	10	9	13	8	12	2	13	2½
Tip of snout to centre of blowhole	—		—		—		11	5	8	10	9	4	13	0	9	3	11	10	11	6	11	6
Tip of snout to posterior insertion of pectoral fin	—		19	0	—		21	0	16	0	17	0	23	0	17	4	24	0	21	0	21	8
Tip of snout to posterior insertion of dorsal fin	—		—		—		49	0	35	0	—		52	9	—		55	0	—		48	8
Eye to ear	—		2	9	—		3	1	2	6	1	11	3	2	—		3	3	—		3	0
Notch of flukes to anus	—		—		—		18	0	14	2	—		19	7	—		19	11	—		16	8
Notch of flukes to umbilicus	—		—		—		28	8	23	5	—		32	0	—		32	4	—		27	0
Length of pectoral fin (tip to anterior insertion)	7	2	7	4	6	7	6	11	5	1	5	8	7	0	5	10	7	1	7	2	6	7
Length of pectoral fin (tip to posterior insertion)	5	4	5	8	5	1	5	3	4	2	4	7	5	9	4	7	5	9	5	2	5	1
Greatest breadth of pectoral fin	1	10	1	11	1	5	1	11	1	5	1	6	2	0	1	4½	2	0	1	8	1	9½
Vertical height of dorsal fin	—		—		—		1	7½	1	1	—		1	9	1	0	1	6½	—		1	4½
Number of breast folds between pectoral fins	—		—		—		62		58		—		84		—		—		—		—	

TABLE V.—*Balænoptera musculus* (L.)—(*continued*).

Measurement	No 19 ♂		No 20 ♀		No 23 ♀		No 24 ♀		No 25 ♀		No 26 ♂		No 27 ♂		No 28 ♀		No 29 ♂		No 30 ♂		No 31 ♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	59	6	59	6	57	3	57	3	66	8	63	0	63	6	59	0	68	9	62	0	67	0
Tip of snout to centre of eye	11	0	11	5	10	10	11	8½	12	9½	12	1½	12	4	11	3½	13	2	11	2½	13	2½
Tip of snout to centre of blowhole	9	9	10	8	9	7	10	5	11	6	11	4	11	0	10	2	11	6	10	0	12	0
Tip of snout to posterior insertion of pectoral fin	19	0	19	3	18	5	19	6	21	10	20	3	20	8	18	7	22	2	18	11	22	2
Tip of snout to posterior insertion of dorsal fin	44	4	—		—		42	9	50	5	47	0	48	0	43	8	—		46	0	51	4
Eye to ear	2	8	—		—		—		3	3	3	1¼	—		2	8	3	2	2	8½	2	11
Notch of flukes to anus	15	10	—		16	3	16	3	17	10	17	11	16	9	16	9	18	2	17	11	18	1
Notch of flukes to umbilicus	26	0	—		26	0	25	6	29	3	28	4	27	6	26	4	29	8	28	0	28	3
Length of pectoral fin (tip to anterior insertion)	6	1	6	2½	6	9½	5	10½	6	7½	6	3	6	9½	5	10½	6	1	6	8¼	7	3
Length of pectoral fin (tip to posterior insertion)	4	7	5	1	4	11½	4	10	5	4	4	9	5	4	4	8	4	11	4	9½	5	5
Greatest breadth of pectoral fin	1	10	1	8	1	7½	1	8	1	10	1	8	1	8½	1	5½	1	11	1	8	1	11
Vertical height of dorsal fin	1	5	—		1	2	1	2½	1	2½	1	3	1	4	1	2	1	9	1	6	1	4½
Number of breast folds between pectoral fins	78		—		—		—		78		70		80		56		—		70		78	

TABLE V.—*Balænoptera musculus* (L.)—(*continued*).

Measurement	No 32 ♂		No 33 ♀		No 34 ♂		No 35 ♂		No 36 ♂		No 37 ♀		No 38 ♂		No 39 ♂		No 40 ♂		No 41 ♂		No 42 ♀	
	Ft	in	Ft.	in.	Ft	in	Ft	in.	Ft.	in	Ft.	in.	Ft.	in	Ft	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	63	0	75	0	64	6	60	0	61	6	66	0	64	6	64	7	62	6	62	6	66	8
Tip of snout to centre of eye .	11	8½	14	0	11	11	11	8	11	8½	13	0	12	0	12	0	12	2	—		14	0
Tip of snout to centre of blowhole	10	6	12	9	10	10	11	0	10	6	12	0	11	0	10	10	11	4	—		12	8
Tip of snout to posterior insertion of pectoral fin	19	7	—		20	6	19	9	20	1	21	7	21	0	20	10	21	0	—		23	10
Tip of snout to posterior insertion of dorsal fin	48	5	56	6	50	1	47	0	47	6	50	11	—		—		48	7	—		—	
Eye to ear	2	11	3	6	3	1	2	10	2	11	3	4	3	1½	—		3	2	—		—	
Notch of flukes to anus . .	16	6	20	1	16	8	15	10	17	3	17	2	17	5	—		16	7	—		—	
Notch of flukes to umbilicus .	26	10	32	9	26	8	25	7	27	0	27	2	—		—		27	0	—		—	
Length of pectoral fin (tip to anterior insertion) . . .	—		8	2	6	10	6	3	6	3	6	9½	6	4½	6	10	6	4½	6	2	6	7
Length of pectoral fin (tip to posterior insertion) . . .	—		6	4	5	2½	4	5	4	11	5	0	4	10½	5	4	4	9	4	8	5	4
Greatest breadth of pectoral fin.	—		2	0	1	8	1	7	1	7	1	10	1	7½	1	1	1	7½	1	7½	1	8
Vertical height of dorsal fin . .	1	3	1	7	1	3	1	7	1	3	1	4½	—		—		1	7	—		—	
Number of breast folds between pectoral fins	82		—		72		72		60		—		—		—		—		—		—	

TABLE V.—*Balænoptera musculus* (L.)—(*continued*).

Measurement	No 44 ♂		No 45 ♀		No 46 ♀		No 47 ♂		No 48 ♀		No 49 ♀		No 50 ♀		No 51 ♀		No 52 ♂		No 53 ♂	
	Ft.	in.	Ft	in.	Ft.	in	Ft	in.	Ft.	in.	Ft	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	59	5	67	8½	60	9	65	7	59	4	68	9	56	9	67	8	58	4	64	7
Tip of snout to centre of eye . . .	11	2	12	6	11	5	12	10½	11	7½	13	6½	11	5½	13	1½	10	9½	11	11
Tip of snout to centre of blowhole .	9	9	11	3	10	3	11	8	10	5	12	9	10	5	—		9	7	10	4
Tip of snout to posterior insertion of pectoral fin	19	8	21	5	19	0	21	10	19	6	23	1	19	1	—		19	0	20	2
Tip of snout to posterior insertion of dorsal fin	—		52	5¼	46	3	50	10	—		52	6	—		—		44	6	—	
Eye to ear	—		3	2½	2	8	3	3½	2	11	3	3	3	2½	—		2	9	3	1
Notch of flukes to anus	—		19	9	17	1	18	3	—		18	8	17	0	—		16	8	—	
Notch of flukes to umbilicus . . .	—		30	0	27	1	29	0	—		30	0	26	2	—		25	10	—	
Length of pectoral fin (tip to anterior insertion)	6	11	7	1½	6	4½	—		6	5	7	2	—		7	5	—		6	8
Length of pectoral fin (tip to posterior insertion)	5	1	5	6½	4	7	—		4	10	5	6	—		5	5	—		5	0
Greatest breadth of pectoral fin . . .	1	7½	1	9	1	6	—		1	6½	1	9	—		1	8	—		1	5
Vertical height of dorsal fin . . .	—		1	6	1	2	1	9	1	1½	1	3	1	8½	—		1	2	—	
Number of breast folds between pectoral fins.	—		80		76		84		—		86		—		—		70		—	

TABLE VI—*Balænoptera musculus* (L.), percentages.

Measurement	No 33 ♀	No 16 ♀	No 14 ♀	No 29 ♂	No 49 ♀	No 45 ♀	No 51 ♀	No 11 ♀	No 9 ♀	No 31 ♂	No 25 ♀
	Ft in.	Ft in.	Ft. in	Ft. in.	Ft. in	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	75 0	74 9	70 9	68 9	68 9	67 8½	67 8	67 3	67 0	67 0	66 8
	%	%	%	%	%	%	%	%	%	%	%
Tip of snout to centre of eye .	18 7	18 3	19 5	19 2	19 7	18 5	19 4	18 9	19 4	19 7	19 2
Tip of snout to centre of blow-hole . .	17 0	15 8	18 4	16 7	18 5	16 6	—	17 1	—	17 9	17 3
Tip of snout to posterior insertion of pectoral fin	—	32 1	32 5	32 2	33 6	31 7	—	31 2	28 4	33 1	32 7
Tip of snout to posterior insertion of dorsal fin	75 3	73 6	74 6	—	76 4	77 5	—	72 8	—	76 6	75 6
Eye to ear	4 7	4 3	4 5	4 6	4 7	4 7	—	4 6	4 1	4 3	4 8
Notch of flukes to anus . .	26 8	26 6	27 7	26 4	27 1	29 2	—	25 6	—	27 0	26 7
Notch of flukes to umbilicus. .	43 7	43 3	45 2	43 2	43 6	44 3	—	42 6	—	42 2	43 9
Length of pectoral fin (tip to anterior insertion) . . .	10 9	9 5	9 9	8 8	10 4	10 5	11 1	10 3	10 9	10 8	9 9
Length of pectoral fin (tip to posterior insertion) . . .	8 4	7 7	8 1	7 2	8 0	8 2	8 1	7 8	8 4	8 2	8 0
Greatest breadth of pectoral fin .	2 7	2 7	2 8	2 8	2 5	2 6	2 5	2 8	2·8	2 8	2 7
Vertical height of dorsal fin .	2 1	2 1	2 5	2 5	1 8	2 2	—	2 4	—	2 1	1 8

TABLE VI.—*Balænoptera musculus* (L.), percentages—(*continued*).

Measurement	No. 42 ♀	No. 37 ♀	No. 17 ♂	No. 18 ♀	No. 47 ♂	No. 8 ♂	No. 39 ♂	No. 53 ♂	No. 34 ♂	No. 38 ♂	No. 27 ♂
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	66 8	66 0	65 7	65 7	65 7	65 0	64 7	64 7	64 6	64 6	63 6
	%	%	%	%	%	%	%	%	%	%	%
Tip of snout to centre of eye. .	21.0	19.7	18.6	20.6	19.6	20.0	18.6	18.5	18.5	18.6	19.4
Tip of snout to centre of blow-hole	19.0	18.2	17.5	17.5	17.8	—	16.8	16.0	16.8	17·0	17.3
Tip of snout to posterior insertion of pectoral fin . .	35.7	32.7	32.0	33.0	33.3	—	32.2	31.2	31.8	32.5	32.5
Tip of snout to posterior insertion of dorsal fin	—	77.1	—	74.2	77.5	—	—	—	77.7	—	75.6
Eye to ear	—	5.0	—	4.6	5.0	—	—	4.8	4.8	4.8	—
Notch of flukes to anus . .	—	26.0	—	25.8	27.8	—	—	—	25.8	27.0	26.4
Notch of flukes to umbilicus .	—	41.2	—	41.1	44.2	—	—	—	41.3	—	43.3
Length of pectoral fin (tip to anterior insertion) . . .	9.9	10.3	10.9	10.0	—	11.0	10.6	10.3	10·6	9.9	10.7
Length of pectoral fin (tip to posterior insertion) . . .	8.0	7.6	7.9	7.7	—	8.2	8.2	7.7	8.1	7.6	8.4
Greatest breadth of pectoral fin .	2.5	2.8	2.5	2.7	—	2.8	1.7	2.2	2.6	2.5	2.7
Vertical height of dorsal fin .	—	2.1	—	2.1	2.6	—	—	—	1.9	—	2.1

TABLE VI.—*Balænoptera musculus* (L.), percentages—(*continued*).

Measurement	No 26 ♂	No 32 ♂	No 40 ♂	No 41 ♂	No. 30 ♂	No 36 ♂	No 46 ♀	No 10 ♀	No 35 ♂	No 19 ♂	No 20 ♀
	Ft. in.	Ft. in.	Ft in	Ft. in.	Ft. in.	Ft in	Ft. in.	Ft. in.	Ft. in.	Ft in.	Ft. in.
Total length	63 0	63 0	62 6	62 6	62 0	61 6	60 9	60 6	60 0	59 6	59 6
	%	%	%	%	%	%	%	%	%	%	%
Tip of snout to centre of eye. .	19.2	18.6	19.5	—	18.1	19.0	18.8	—	19.4	18.5	19.2
Tip of snout to centre of blow-hole	18.0	16.7	18.1	—	16.1	17.1	16.9	—	18.3	16.4	17.9
Tip of snout to posterior insertion of pectoral fin	32.1	31.1	33.6	—	30.5	32.6	31.3	—	32.9	32.0	32.3
Tip of snout to posterior insertion of dorsal fin.	74.6	76.8	77.7	—	74.2	77.2	76.1	—	78.3	74.5	—
Eye to ear	4.9	4.6	5.0	—	4.4	4.7	4.4	—	4.7	4.5	—
Notch of flukes to anus . .	28.4	26.2	26.5	—	28.9	28.0	28.1	—	26.4	26.6	—
Notch of flukes to umbilicus .	45.0	42.6	43.2	—	45.1	43.9	44.6	—	42.6	43.7	—
Length of pectoral fin (tip to anterior insertion) . . .	9.9	—	10.2	9.9	10.8	10.2	10.5	10.9	10.4	10.2	10.4
Length of pectoral fin (tip to posterior insertion) . . .	7.5	—	7.6	7.5	7.7	8.0	7.5	8.4	7.4	7.7	8.5
Greatest breadth of pectoral fin .	2.6	—	2.6	2.6	2.7	2.6	2.5	2.3	2.6	3.1	2.8
Vertical height of dorsal fin .	2.0	2.0	2.5	—	2.4	2.0	1.9	—	2.6	2.4	—

TABLE VI.—*Balænoptera musculus* (L.), percentages—(*continued*).

Measurement	No 44 ♂	No 48 ♀	No 28 ♀	No 52 ♂	No 23 ♀	No 24 ♀	No 50 ♀	No 13 ♂	No 15 ♀	No 12 ♂
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	59 5	59 4	59 0	58 4	57 3	57 3	56 9	55 3	54 3	53 3
	%	%	%	%	%	%	%	%	%	%
Tip of snout to centre of eye	18·8	19·6	19·1	18·5	18·9	20·4	20·2	18·8	19·8	18·3
Tip of snout to centre of blowhole . .	16·4	17·6	17·2	16·4	16·7	18·2	18·3	16·9	17·0	16·6
Tip of snout to posterior insertion of pectoral fin	33·1	32·9	31·5	32·6	32·2	34·0	33·6	30·8	31·9	30·0
Tip of snout to posterior insertion of dorsal fin	—	—	74·0	76·3	—	74·7	—	—	—	65·7
Eye to ear	—	4·9	4·5	4·7	—	—	5·6	3·5	—	4·7
Notch of flukes to anus	—	—	28·4	28·6	28·4	28·4	29·9	—	—	26·6
Notch of flukes to umbilicus	—	—	44·6	44·3	45·4	44·5	46·1	—	—	44·0
Length of pectoral fin (tip to anterior insertion)	11·6	10·8	9·9	—	11·8	10·3	—	10·3	10·8	9·5
Length of pectoral fin (tip to posterior insertion)	8·5	8·1	7·9	—	8·6	8·4	—	8·3	8·4	7·8
Greatest breadth of pectoral fin . . .	2·7	2·6	2·5	—	2·8	2·9	—	2·7	2·5	2·6
Vertical height of dorsal fin	—	1·9	2·0	2·0	2·0	2·1	3·0	—	1·9	2·0

TABLE VII.—*Balænoptera musculus* (L.).

Measurement	Average Per Cent of Total Length	
	European (Irish)	American
Tip of snout to centre of eye . . .	(38) 19.4	(10) 20.6
Tip of snout to centre of blowhole . .	(35) 17.3	(8) 18.4
Tip of snout to posterior insertion of pectoral fin	(35) 32.3	(5) 33.2
Tip of snout to posterior insertion of dorsal fin	(24) 75.8	(8) 77.1
Eye to ear	(28) 4.7	—
Notch of flukes to anus.	(28) 27.3	—
Notch of flukes to umbilicus . .	(27) 43.6	—
Length of pectoral fin (tip to anterior insertion)	(36) 10.4	—
Length of pectoral fin (tip to posterior insertion)	(36) 8.0	—
Greatest breadth of pectoral fin . . .	(36) 2.6	(10) 2.9
Vertical height of dorsal fin . . .	(28) 2.2	(10) 2.4

TABLE VIII.—*Balænoptera sibbaldii* (Gray).

Measurement	No 2 ♀		No 3 ♀		No 4 ♀		No 5 ♀	
	Ft	in	Ft.	in.	Ft.	in.	Ft	in.
Total length	83	0	84	0	64	6	70	0
Tip of snout to centre of eye	15	7	16	5	12	5	13	9½
Tip of snout to centre of blowhole	13	6	15	0	10	8	12	0
Tip of snout to posterior insertion of pectoral fin	25	8	28	8	21	6	23	9
Tip of snout to posterior insertion of dorsal fin	61	0	62	5	47	4	53	9
Eye to ear	3	11	—		3	4½	3	8
Notch of flukes to anus . .	22	9	22	11	18	6	18	11½
Notch of flukes to umbilicus .	35	8	36	6	28	7	29	7
Length of pectoral fin (tip to anterior insertion)	10	2	9	11	9	0	8	11
Length of pectoral fin (tip to posterior insertion) . .	8	1	7	4½	7	6	7	0
Greatest breadth of pectoral fin .	2	9½	2	11	2	5	2	5
Vertical height of dorsal fin .		8½		10		6½		6½
Number of breast folds between pectoral fins	70		70		74		78	

True compares his percentages with some compiled by him from different European specimens, but the largest number of individuals giving a corresponding average is eight. He finds that his two series of percentages agree very well, but it appears that even here most of the average percentages of the European specimens tend to be lower than the corresponding figures for the American animals Unfortunately all the figures in the first column of Table VII could not be compared, as True does not give the percentages for the corresponding measurements The breadth of the pectoral fin and the vertical height of the dorsal fin correspond very closely in both columns, but the first four measurements all show a difference of about 1.1 per cent. The

TABLE IX.—*Balænoptera sibbaldii* (Gray), percentages.

Measurement	No. 3 ♀	No. 2 ♀	No. 5 ♀	No. 1 ♀
	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	84 0	83 0	70 0	64 6
	%	%	%	%
Tip of snout to centre of eye .	19·5	18·8	19·7	19·3
Tip of snout to centre of blow-hole	17·8	16·3	17·1	16·5
Tip of snout to posterior insertion of pectoral fin	34·1	30·9	33·9	33·3
Tip of snout to posterior insertion of dorsal fin	74·3	73·5	76·8	73·4
Eye to ear	—	4·7	5·2	5·2
Notch of flukes to anus . .	27·3	27·4	27·1	28·7
Notch of flukes to umbilicus .	43·4	43·0	42·3	44·3
Length of pectoral fin (tip to anterior insertion)	11·8	12·3	12·7	13·9
Length of pectoral fin (tip to posterior insertion)	8·8	9·7	10·0	11·6
Greatest breadth of pectoral fin .	3·5	3·4	3·4	3·7
Vertical height of dorsal fin .	0·99	0·85	0·77	0·84

TABLE X.—*Balænoptera sibbaldii* (Gray).

Measurement	Average Per Cent. of Total Length		
	European (Irish) ♀		Newfoundland Specimen ♀ (True)
Tip of snout to centre of eye . . .	(4)	19·3	21·6
Tip of snout to centre of blowhole .	(4)	16·9	19·9
Tip of snout to posterior insertion of pectoral fin	(4)	33·0	34·3
Tip of snout to posterior insertion of dorsal fin	(4)	74·5	76·9
Eye to ear	(3)	5·0	—
Notch of flukes to anus	(4)	27·6	—
Notch of flukes to umbilicus . .	(4)	43·2	—
Length of pectoral fin (tip to anterior insertion)	(4)	12·7	—
Length of pectoral fin (tip to posterior insertion)	(4)	10·0	11·1
Greatest breadth of pectoral fin . . .	(4)	3·5	3·8
Vertical height of dorsal fin . . .	(4)	0·86	0·96

cannot be a question of units, as the method of taking percentages obviates this difficulty.

It certainly appears as if the individuals of what is probably one *species* on either side of the Atlantic differ somewhat more than True supposes in their general proportions. In discussing the question of proportions in this species it is interesting to notice that the proportions in those whales examined which had fed on herrings, viz., Nos. 8, 9, 10, and 48, Table V., do not differ appreciably from the figures obtained in the case of individuals which had fed on 'krill.'

2. *Balænoptera sibbaldii* (Gray).—In Table VIII. we have a similar

set of measurements for *B. sibbaldii* as that just considered for the common 'Finner.' The measurements were taken in exactly the same way as those already discussed

There are only four individuals to be considered in this case, so that the averages are not so trustworthy.

Table IX. gives the measurements reduced to percentages of the total length, the individuals being arranged in order of size, as in Table VI.

Table X. shows the average percentages compared with corresponding figures obtained by True from a Newfoundland female measured by himself.[32] Here again the proportions of the Irish specimens are smaller than those obtained for the American individual

In this case the differences are greater than those found from Table VII, varying from 0 1 to 2 4 per cent It is impossible to account for these differences at present, and it will be necessary for a larger number of European specimens of this species to be measured accurately before a careful comparison can be made

VI Colour

1 *Balænoptera musculus* (L)—There is no doubt that the colour disposition in this species is variable, but the differences in the descriptions given by European authors are probably greater than the variations which are actually found among the living animals This is due to the fact that the pigmented parts darken comparatively rapidly on exposure to the air, after the animal is dead After a whale is killed it is brought to the station floating back downwards in the water, as stated above, so that if an examination be made as soon as the carcase is drawn up on the slip the errors due to darkening will probably not be very large, as the greater part of the pigment is found on the back, which has not been exposed to the air The disposition of the light and dark portions will be even less affected than the actual shade of colour

The specimens examined showed a certain number of minor variations, but the general colour-scheme was remarkably constant This scheme was substantially the same as that given by Sars in 1866 [33]

The curious asymmetry of colour in the jaws and baleen of this species was found to be very constant There appears to be always more pigment on the left side of the body than on the right Guldberg states that the asymmetry may be reversed,[34] and that the greater amount of pigment may be on the right side True's observations do not bear out this statement, and he concludes that the right side is always less pigmented than the left My own observations entirely support True's conclusion In the specimens examined by me the greater amount of pigment always occurred on the left side A few of the individual variations in the amount and disposition of the pigment in specimens examined serve to show the kind of variation which occurs

[32] True. *op cit*, p. 159.

[33] G. O Sars, *Chris. Videns-Selsk Forhandl*, Aar 1865, 1866, pp 266-295, translated by True, *op cit*, p 120

[34] Vide also Beddard, 'A Book of Whales,' p. 158.

No 10, ♀, *length* 60 *feet* 6 *inches*—The left lower jaw was pale grey at its root, but shaded gradually to the general dark slate-colour in front All the baleen-plates were dark grey on the left side, very slightly paler in colour towards their inner edges.

On the right side the anterior one-third of the baleen-plates were yellowish-white, then came a few with grey longitudinal stripes, and the rest were dark grey as on the left side

No. 11, ♀, *length* 67 *feet* 3 *inches*—All the under-side was pure white, the upper dark slate-grey, the dark colour sloping down the sides, beginning above the genital opening, and the white underneath portion being reduced to a strip about two inches wide from the root of the tail to half-way between the tail and anus There was a fairly large greyish patch with very irregular edges situated above the right eye, and extending along the outside of the right upper jaw The under-side of the front half of the right upper jaw was pure white This was sharply marked off from the grey of the rest of the jaw. The white began just behind the level at which the baleen became yellow-white The left jaw was all of the dark slate-grey All the baleen-plates in the left jaw were dark slate-grey, almost black On the right side the first 119 plates were yellowish-white, the rest dark grey The bristles were yellowish on the light-coloured plates, but pale grey on the dark The total number of plates on the right side was 380

No 12, ♂, *length* 53 *feet* 3 *inches*—The general coloration was normal The under-side of the body was white except in the depressed creased part of some of the breast folds, which had patches of the dark-grey colour A light-grey irregular patch extended up the side in front of the right pectoral fin The under-side of the pectoral fins were white, and this white extended round the lower edge of the fin for about 1½ inch A light-grey line about ½ inch wide and 1½ foot long ran backwards and upwards from the ear-opening The breast folds were less pigmented than in No 11

No 15, ♀, *length* 54 *feet* 3 *inches*—The dorsal coloration was lighter than usual, although the animal had been dead some time There appeared to be none of the large greyish spots usually present on the upper part of the body. The right pectoral fin was of a very pale colour, and there was less pigmentation around the insertion than on the distal part

No 17, ♂, *length* 65 *feet* 7 *inches*—Colour normal over the body On the left pectoral fin the white only just extended round the front edge A light-grey mark stretched across the outer side at the level of the posterior point of insertion On the right pectoral fin the white colour extended round the front edge, and for nearly one-quarter of the way across the outer surface.

No. 18, ♀, *length* 65 *feet* 7 *inches.*—A dark individual. The dark colour extended further than usual in irregular patches on the under-side near the notch of the flukes.

No 25, ♀, *length* 66 *feet* 8 *inches*—The front half of the right upper jaw was of a pink colour, similar to that of the palate.

No 28, ♀, *length* 59 *feet*—The two dark streaks which normally start half-way up the side and half-way between the anus and the root

of the tail, running slightly downward and then horizontally forward, ended about 1 foot 3 inches behind the anus, and were here about 7 inches apart. Generally these streaks run forward right up to the anus.

No. 32, ♂, *length* 63 *feet*.—A very dark individual, although examined while quite fresh. The dark colour extended on the breast folds as well as in the furrows down to the mid-ventral line.

No. 36, ♂, *length* 61 *feet* 6 *inches*.—This individual showed very clearly all the different kinds of light spots which are found on this animal. There are (*a*) narrow tadpole-shaped white spots, 1 inch to 1½ inch long, (*b*) small oval white spots, ¼ inch long, (*c*) large oval grey spots, with radiating dark lines,[35] about 2½ inches by 1 inch at the broadest part; and (*d*) rings and patches of small grey spots. The rings are generally about 2 inches in diameter. These different kinds of spots are very variable in their intensity and distribution, and may be absent in some cases.

The conclusion which must be drawn from these observations is that while variations in the intensity and distribution of the colour are very common, yet in no case do the differences from the accepted type warrant the creation of even a sub-species.

2. *Balænoptera sibbaldii* (Gray).—The colour of the four individuals examined by me did not show any great variation from the normal. They were of a bluish-black all over as the ground-colour, with light-grey fleckings and spots irregularly placed over the back. The grey fleckings were especially noticeable in the region of the umbilicus, extending up the sides.

The breast folds from the front end to the level of the insertion of the pectorals was of the same colour as the back. Behind this there were more white marks placed irregularly on the folds and ridges. The whole of the upper jaw on both sides was of the uniform dark colour. The front inner part of the under jaw on both sides was a light-grey colour, with the dark colour in spots and fleckings. Both the plates and bristles of the baleen were black. The palate was also of the dark blue-black colour, not pink as in *B. musculus*. The variations from this scheme were inconsiderable in the four individuals.

No. 3[36] had a patch of bright yellow on the breast folds, situated near the mid-ventral line, just behind the level of the insertion of the pectoral fins. The patch extended over about five ridges and was about 5 feet long.

No. 4 was a lighter-coloured individual than usual.

VII. Body Form.

This was very constant both for *Balænoptera musculus* and for *Balænoptera sibbaldii*. It will be seen by reference to Tables VII. and X. that the dorsal fin of *B. sibbaldii* is relatively much smaller than that of *B. musculus*. In other proportions there is no very striking difference between the two species.

Injuries in the form of large, irregular notches were fairly common

[35] Vide Collett, *Proc. Zool. Soc.*, 1886, p. 249, pl. xxvi., fig. 2. (*B. borealis*).
[36] Vide Table III.

in both species The tip of the pectoral fin was the part most commonly injured. Probably some blubber-eating fish may account for these abnormalities

In both species there was found to be a certain amount of variation in the shape of the dorsal fin, although its position was fairly constant.

VIII THROAT FURROWS.

1. *Balænoptera musculus* (L)—The number of the grooves counted between the insertion of the pectoral fins varies from 56 in No. 28 (Table V) to 86 in No 49 It will be seen that there is no correlation between the number of furrows and the sex or size of the animal The average number deduced from 19 observations is 73

The furrows extend from the tip of the mandible to the navel From the level of the pectoral fins to the navel the furrows anastomose somewhat irregularly The ridges between the furrows are nearly always pure white in this species, but the dark blue-grey colour is often found in the furrows, being sometimes present to a greater extent on the left than on the right side The size of the grooves is fairly constant, being from 1 to $1\frac{1}{2}$ inch wide when unextended The ridges are about the same width

Lillie [37] suggests that the pink colour sometimes found in the throat grooves may be due to high vascularisation, and may thus help to aerate the blood After an examination of several animals in which this pink colour occurred, I have come to the conclusion that the colour is certainly due to blood, but I think it must be considered as a blood effusion occurring after the death of the animal If it were an adaptation for securing a greater aeration of the blood, and so to allow the animal to remain under water longer than it otherwise could, we should expect it to occur much more often than it does Also the pink colour, when it occurs, is generally only in patches

2 *Balænoptera sibbaldii* (Gray) —The throat-grooves in this species are arranged very much as in the common ' Finner ' The number in the individuals examined varied from 70 to 78, and the average number was 73 A yellowish tinge sometimes occurs on the ridges, as mentioned above under VI 2

IX WHALEBONE

1 *Balænoptera musculus* (L)—The baleen of this species was fairly thick, with moderately fine bristles The number of yellowish plates on the right side varies somewhat, as does also the width and number of dark longitudinal stripes which are found on these plates

The average number of plates along one side of the upper jaw was 383

The number of white plates in the front part of the right upper jaw varied from about 140 to 180

The average greatest length of a plate of whalebone, measured from the gum to the tip of the plate, was 1 foot 8 inches.

The bristles were never black, but either dirty white or yellow.

[37] Lillie, *Proc. Zool. Soc* , 1910, 2, p 784.

2. *Balænoptera sibbaldii* (Gray).—The whalebone of this species is thicker than that from the 'Finner.' The colour is of a uniform dark blue-black colour, both plates and bristles. The average number of plates was about 314, and their average greatest length, measured as above, was 2 feet 1 inch.

X. Hairs.

1. *Balænoptera musculus* (L.).—Hairs occur in three positions in these animals. At the tip of the mandible and running along the line of the symphysis on each side, there were found two rows of short hairs, from ¼ to ½ inch in length. The hairs are situated about 1 inch apart. The number of hairs in this position is variable, the minimum number found being twenty-four (No. 12, Table I.), and the maximum forty (No. 30, Table I.). Hairs were also found situated on the dorsal side of the head in the beak region. These were arranged in two main rows on either side, the inner row on each side curving round the blow-holes. The rows were not found to be so regular as those shown by Lillie,[38] however. On each side the rows began about 6 inches from the tip of the snout. There were about twelve hairs on each side, or twenty-four hairs in all in this position. There was also a row of hairs on either side running along the outer side of the lower jaw and parallel with the edge. These two rows each consist of from six to ten hairs.

When a hair is situated on a dark portion of the skin, there is often a light-grey ring round its base, but this ring is not invariably present. When the hair is situated on a pale portion of the skin, *e.g.*, on the tip of the mandible, we generally find a dark ring round the base. No sebaceous glands connected with these hairs could be found.[39] There appeared to be a small nerve connected with the papilla of each of these hairs,[40] so that they probably have some sensory function, *e.g.*, the detection of food.

2. *Balænoptera sibbaldii* (Gray).—The distribution of hairs in this species is almost exactly similar to that in the common 'Finner.' The number of hairs in the different positions is not quite the same in the two species, however. At the tip of the lower jaw there generally appeared to be about forty hairs. In No. 5, Table III., there were forty-four. Along the top of the beak we have about fifteen hairs on each side, or thirty in all. The number along the edge of the lower jaw is generally six. The hairs are of the same dirty-white colour as in *Balænoptera musculus*, but there is never a light-grey ring round the base of any of the hairs.

XI. Jacobson's Organ.

This organ[41] appears to be represented only by the ventral ends of Stenson's duct on each side, which open underneath the tip of the snout. The openings are situated about 3 inches from the tip of the

[38] Lillie, *Proc. Zool. Soc.*, 1910, 2, p. 774.

[39] So also Kukenthal, 'Walthiere,' in *Denkschr. Med.-Nat. Gesells.*, *Jena*, 1889.

[40] Vide Japha, *Zool. Jahrb.*, xxiv.

[41] Lillie, *Proc. Zool. Soc.*, 1912, 2, p. 784; Kukenthal, *op. cit.*, p. 349, vol. ii.

snout, and are about $1\frac{1}{2}$ inch apart. They consist of a pair of shallow oval depressions (longest ones about $\frac{3}{4}$ inch and $1\frac{1}{2}$ inch). At the hinder end of each of these depressions and partly closed by a small flap-like projection is a short canal running backwards and slightly upwards. These canals are from $\frac{1}{2}$ inch to 1 inch in length in *B. musculus* when present, but in some cases, *e.g.*, in Nos. 16 and 49, Table I., the canals were absent, and only the depressions remained. In *B. sibbaldii* the canals seem to have disappeared entirely, and in all the specimens examined only the depressions remained, situated in a similar position to those in *B. musculus*.

The original function of Jacobson's Organ was probably to bring the food taken into the mouth under the direct control of the olfactory nerve. This function has apparently been entirely lost in the whales, and the lower end of Stenson's duct is all that remains, now entirely cut off from the main nasal organ. The fact that even these ducts may be absent points to the conclusion that this last vestige is in the process of extinction.

XII. Contents of the Stomach

1. *Balænoptera musculus* (L.)—The stomachs of the first three whales examined (Nos. 8, 9, 10, Table I) contained large numbers of small fish. The length of the largest of these fish was about 5 inches From the somewhat damaged specimens taken these fish appear to be small herrings. Whale No. 48, Table I., was said to be a 'Herring Whale,' but there was very little food in the stomach. The little there was appeared to be the remains of small fish

In all other whales of this species the pharynx and stomach were full of a small red crustacean which appears to be *Meganyctiphanes norvegica* (M. Sars). This small crustacean forms the 'krill' of the whalers In the stomach the crustacea are reduced to a terracotta-coloured fluid, in which the eyes float as bluish spots The fæces consist of a semi-solid terracotta mass.

2 *Balænoptera sibbaldii* (Gray)—In all cases these whales appear to have fed on the 'krill,' nothing else in the way of food ever being found in their stomachs.

XIII. The Eye.

The eye is very similar in *B. musculus* and in *B sibbaldii* The length of the eye-opening *in situ* is from 4 to 5 inches, and vertical width $1\frac{1}{2}$ inch to 2 inches in the dead animal When alive the vertical width of the opening is probably about 3 inches. The eyeball forms a globe of about 5 inches to $5\frac{1}{2}$ inches diameter The long axis of the iris is from $1\frac{1}{2}$ inch to 2 inches, and that of the pupil from $\frac{3}{4}$ inch to $1\frac{1}{4}$ inch.

At the anterior commissure of the eyelids there is a ridge with a short groove above and below, and there are one or two short grooves at the posterior commissure of the eyelids. There are also both above and below the eye one or two furrows which vary slightly in number and position The eyelids do not appear to be very mobile The iris is brown, with a bluish-white, narrow, irregular border.

The pupil is elongated antero-posteriorly and has a peculiar shape. When expanded the pupil is nearly in the shape of a half-ellipse, the curved side being ventral. On contraction the curved part remains practically stationary, and the upper, originally nearly flat, boundary is allowed to drop downward. When closed the pupil is practically in the form of a semicircular line with the convexity downwards. This peculiar shape of pupil is found also in the bottlenose porpoise.[42]

The internal structure of the eye, as far as could be ascertained from the specimens examined, conformed to the normal mammalian type, with certain modifications which are usually considered to be adaptations to an aquatic mode of life. These consist chiefly in the presence of a thick sclerotic, a flattened and fairly thick cornea, and a nearly globular lens All these modifications are well marked in the eyes of *B. musculus* and *B. sibbaldii.*

The chief points of anatomical detail noticed were:—

(*a*) No Meibomian glands could be found in connection with the eyelids

(*b*) The musculature of the iris is well developed.

(*c*) The choroid is thin, and the ciliary muscle appears to be entirely absent

(*d*) There are four large venæ vorticosæ in the sclerotic

(*e*) There are many rods and cones in the retina, of medium length The most noticeable thing about the retina is the large number of elements composing the outer nuclear layer, which is much thicker than the inner

XIV Parasites

A *External*

1 *B. musculus* (L)—In about half a dozen cases the parasitic copepod *Penella balænoptera* (Kov and Dan) was found on the body of this species The external portion of the body of these parasites averaged about 6 inches in length The parasite was of a black colour, except the egg-sacs of the female, which were in the form of long, narrow brown strings, less than a millimetre broad and about as long as the projecting part of the body of the parasite

These parasites are generally found all through the season, and the most usual position is on the body-wall not far behind the ear-opening. In some cases they were found on the side of the whale, near the tail The greatest number found on one whale was six.

The other external parasite found on this species is the copepod *Balænophilus unisetus* (Aurivillius) These occur on the baleen-plates. Both nauplius larvæ and adults are found on the plates, and when large numbers of nauplii are present they are situated chiefly on the outer sides of the plates. When few of these parasites are present they are generally on the inner sides of the plates. This parasite was not present on every specimen of *B. musculus* examined.

2 *B. sibbaldii* (Gray)—The small copepod *Balænophilus unisetus*

[42] True, *Proc U S Nat Mus*, vol xiii, p 197

(Auriv) was universally present on the baleen-plates of the 'Blue whale.' No other external parasites were found on this species.

B *Internal*

1 *B musculus* (L)—In the individual labelled No 13 in Table I. a small number of worm-like animals were found They were attached by one end to the mucous membrane of the second chamber of the stomach, which contained no food They were about 1¼ inch long, and only four were found These are certainly Echinorhynchi, but the exact species has not yet been determined The presence of Echinorhynchi in the stomach of this species does not seem to have been recorded until now.

In one individual [No 12, Table I] about half a dozen small oval white bodies were found very loosely attached to the wall of the intestine These have been identified as the Trematode *Monostomum plicatum* (Creplin) [43] Their anatomy has been fully worked out by L A. Jagerskiold [44] They are about 6 mm long and 3 mm broad The most interesting thing about them is that they have longitudinal striations on the under-surface, which no doubt help them in attaching themselves to the mucous membrane of the intestine Creplin fancifully compares these striations to the throat-grooves of the whale

2 *B sibbaldii* (Gray)—The intestines of individuals of this species often contained large numbers of an Echinorhynchus, which has been identified as *Echinorhynchus brevicollis* (Malm) [45] No other internal parasites were found

XV PROBLEMATICAL ORGANS

In *Balænoptera musculus*, just inside the tip of the lower jaw, over the symphysis, were noticed two small openings, each partly covered by a small valve-like flap The skin just around these openings and on the valve-flap was yellowish white The openings were about ¾ inch apart, and they lead into a small canal, which soon branches into three or four The longest of these extends backwards and slightly downwards, and is about 1 inch in length.

In the case of *B sibbaldii* each spot marked the position of the openings of about four very narrow canals, each of which was about 1 inch in length These openings in each species appear to be quite constant in form and position In both cases the outer integument appears to be tucked in for the whole course of the tubes In one preparation there appeared to be some mucus-like substance in the tube, but no structures comparable to glands opening into the tubes could be discovered. On account of the very tough connective tissue around the symphysis of the lower jaw, the portions with these canals are very difficult to work with in cutting sections

The function of these organs is quite obscure, and I can find no

[43] Creplin, *Nov Act Acad N.C*, xiv, p 873

[44] Jägerskiold, *Kgl Svenska. Vitensk Akad Handlinger*, Bd. 24, No 7, 1891 (called here *Ogmogaster plicatus*).

[45] Malm, 'Monogr. Illustr Balænopt . . . côte occ. de Suède,' fol., Stockholm, 1867.

reference to them in literature. It is necessary that further specimens should be carefully preserved and examined.

XVI. Fœtuses

An effort was made to obtain a fœtus small enough for embryological work, but with no success The genital organs of the adult are so large, compared with the size of the fœtus required, that even if one of the latter be present there is a great chance that it will be lost among the entrails of the mother. Also it will be seen from the remarks above on breeding that there would be a much greater chance of obtaining a very young fœtus in the earlier part of the season

Nine fœtuses were examined altogether Of these, eight were *Balænoptera musculus* (L), and one *Balænoptera sibbaldii* (Gray) All the fœtuses lay with the head towards the vagina of the mother.

1 *Balænoptera musculus* (L)

A *Measurements* —A complete set of measurements, similar to those taken on the adults, was obtained for six of the fœtuses. Table XI is constructed in the same way as Tables I and III From this we see that the total length of the fœtuses varied very much during the earlier part of the season, but tended to get larger towards the latter part The table also shows that, out of seven individuals, five were females and two males This indicates that, although fewer females may be caught, they are at least as numerous as the males Table XII shows the set of measurements made on six individuals. In this table the distances between the tips of the tail-flukes is included, as this measurement could be made on the fœtuses In Table XIII we have the measurements reduced to percentages of the total length in each case, and the individuals are arranged in order of size Table XIV. shows the average percentages of each of the twelve distances taken. If we compare these figures with those in the first column of Table VII , we see that, while many agree very well, there are one or two exceptions The figures for the distance between the tip of the snout and the centre of the blowhole show that the latter is nearer the tip in a fœtus of between 5 and 9 feet than it is in the adult The other noticeable point is that both the pectoral and dorsal fins are larger relatively in these fœtuses than in the average adult.

Table XI.—*Balænoptera musculus* (L.). Fœtuses.

Capture No	Date	Length of Adult		Length of Fœtus		Sex of Fœtus
		Ft.	in.	Ft.	in.	
14	July 12	70	9	8	11	♂
16	July 16	74	9	4	11	♀
18	July 20	65	7	8	5	♀
25	July 24	66	8	6	0	♀
33	Aug. 7	75	0	5	6	?
37	Aug. 11	66	0	9	0	♀
49	Sept. 10	68	9	9	0	♀
51	Sept. 18	67	8	9	3	♂

TABLE XII.—*Balænoptera musculus* (L.), Fœtuses.

Measurement	No 14 ♂		No 16 ♀		No 18 ♀		No 25 ♀		No 37 ♀		No 51 ♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length . . .	8	11	4	11	8	5	6	0	9	0	9	3
Tip of snout to centre of eye	1	9		11	1	7	1	2½	1	8½	1	8
Tip of snout to centre of blowhole . . .	1	4		8½	1	4		10½	1	4	1	4½
Tip of snout to posterior insertion of pectoral fin	—		1	8	2	10½	2	1	3	0	3	2
Tip of snout to posterior insertion of dorsal fin	6	10	3	8⅛	6	2½	4	5	6	9	7	0
Eye to ear . . .		9½		3		6		?2		6		7
Notch of flukes to anus	2	9	1	6	2	6	1	9½	2	7	2	10
Notch of flukes to umbilicus . .	4	4	2	4½	3	9½	2	8½	3	9	4	3
Length of pectoral fin (tip to anterior insertion)	1	3½		7½	1	1		9	1	3	1	4
Length of pectoral fin (tip to posterior insertion)	1	0		5½		9½		6¼	1	0		11
Greatest breadth of pectoral fin. . .		4		1¾		3½		2¼		3½		4
Vertical height of dorsal fin		3½		1¼		4		2		3½		3½
Flukes (tip to tip) .	1	7		11½	—		—		1	2	1	8
Number of breast folds between pectoral fins	70		60		86		64		—		60	

B *Colour.*—In all the fœtuses the upper part of the body was similar to that of the adult, but the under-side was a deep-pink colour This appears to be due to an effusion of blood into the skin, and has been noted in the case of *Mesoplodon bidens* by Southwell and Harmer.[46]

C. *Body Form.*—This in all the fœtuses was the same as that of the adult Thus, the smallest fœtus examined, which was about one-quarter the average size at the end of gestation, was entirely like the adult in form, except that it was less robust. The tail-flukes in all the fœtuses were markedly bent towards the ventral side of the animal, so as to present a very concave ventral surface In obtaining the distance between the tips of the flukes the latter were stretched apart as far as they would go, but they could not be stretched out as flat as they appear in the adult.

D. *Throat Furrows* —These were as fully formed as in the adult The average from the numbers in five individuals was sixty-eight, a number closely agreeing with that obtained from the adults

E. *Whalebone* —This was not developed sufficiently to show through the gum in any of the fœtuses, but if a thin strip were taken from the inner edges of the upper jaw the rudiments of the plates could be seen.

[46] T Southwell and S. F. Harmer, *Ann. and Mag. Nat. Hist.*, 6, vol. xi, April 1893.

TABLE XIII.—*Balænoptera musculus* (L.), Fœtuses, Percentages.

Measurement	No 51 ♂	No 37 ♀	No 14 ♂	No 18 ♀	No 25 ♀	No 16 ♀
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	9 3	9 0	8 11	8 5	6 0	4 11
	%	%	%	%	%	%
Tip of snout to centre of eye	18·0	19·0	19·6	18·8	20·1	18·6
Tip of snout to centre of blowhole	14·9	14·8	14·9	15·8	14·6	14·4
Tip of snout to posterior insertion of pectoral fin	34·2	33·3	—	34·2	34·7	33·9
Tip of snout to posterior insertion of dorsal fin	75·7	75·0	76·6	73·8	73·6	75·4
Eye to ear	6·3	5·6	8·9	5·9	?2·8	5·1
Notch of flukes to anus	30·6	28·7	30·8	29·7	29·9	30·5
Notch of flukes to umbilicus	46·0	41·7	48·6	45·1	45·1	48·3
Length of pectoral fin (tip to anterior insertion)	14·4	13·9	14·5	12·9	12·5	12·7
Length of pectoral fin (tip to posterior insertion)	9·9	11·1	11·2	9·4	8·7	9·3
Greatest breadth of pectoral fin	3·6	3·2	3·7	3·5	3·1	3·0
Vertical height of dorsal fin	3·1	3·2	3·3	3·9	2·8	2·1
Flukes (tip to tip)	18·0	13·0	17·7	—	—	19·5

TABLE XIV.—*Balænoptera musculus* (L.), Fœtuses

Measurement	Average Per Cent of Total Length
Tip of snout to centre of eye	(6) 19·0
Tip of snout to centre of blowhole	(6) 14·9
Tip of snout to posterior insertion of pectoral fin	(5) 34·0
Tip of snout to posterior insertion of dorsal fin	(6) 75·0
Eye to ear	(5) 6·3
Notch of flukes to anus	(6) 30·0
Notch of flukes to umbilicus	(6) 45·8
Length of pectoral fin (tip to anterior insertion)	(6) 13·5
Length of pectoral fin (tip to posterior insertion)	(6) 9·9
Greatest breadth of pectoral fin	(6) 3·3
Vertical height of dorsal fin	(6) 3·0
Width of flukes (tip to tip)	(4) 17·0

F *Hairs*.—These were examined carefully in the fœtus labelled No. 14. The numbers and distribution of the hairs at the tip of the lower jaw, and also along the top of the snout, were similar to those in the adult.

Along the outer edge of the lower jaw there were ten hairs, arranged

in one row of eight, and the other two below this row and about half-way along it. This arrangement was similar on both sides

G *Jacobson's Organ* —The rudiments of this organ were in a similar condition to that found in the adults

H *Ovaries* —The ovaries from a fœtus 6 feet long [No. 25, Table XI] were about $2\frac{1}{4}$ inches long They were firmly embraced by the upper ends of the Fallopian tubes Both ovaries were equally developed Their outer surface was much furrowed This may have been accentuated by the preservative, but they were distinctly furrowed

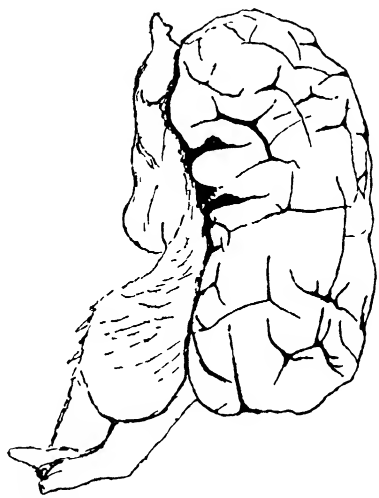


Fig. 4.—Ovary (nat. size), *B. musculus*. No. 25 Fœtus. (Del. ad Nat.—S.T.B.)

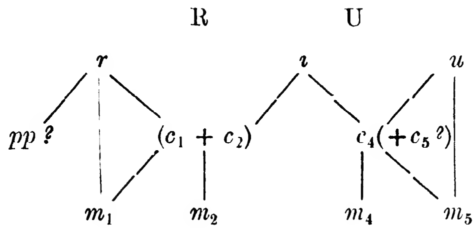
when quite fresh [fig 4]. A transverse section shows young follicles, connective tissue, and blood-vessels as usual

I. *Testes* —The testes from fœtus No 51, 9 feet 3 inches long, were about $2\frac{1}{2}$ inches long, and were equally developed and closely attached to the upper end of the vas deferens The outer surface was smooth, and not furrowed as in the ovaries A transverse section showed numerous follicles with developing sperm mother-cells The follicles were separated by well-marked strands of connective tissue, and there was a large blood-supply.

J. *Thymus* —This organ consisted of two main oval bodies, each about 2 inches long, in a fœtus of 5 or 6 feet They were situated on the base of the great vessels of the heart, and showed on their surface a finely lobulated structure A transverse section showed the normal mammalian structure, free nuclei, small cells, large cells, and concentric corpuscles, with well-marked strands of connective tissue dividing up the whole body into lobules.

K. *Flippers* —These were taken from a fœtus of 6 feet [No 25], to see whether anything of the extra digit mentioned by Kukenthal remained to this stage On dissection no trace of this digit was found,

although its presence in the flippers of very small fœtuses obtained from another source has been confirmed. The scheme for the arm and wrist bones agrees with that given by Kukenthal,[47] thus:—



The formula for the number of phalanges, supposing the third finger to be missing, may be arranged thus:—

I, 4, II, 7, IV, 6; V, 4.

L. *Problematical Organs.*—In the one large fœtus (9 feet 3 inches) which I was enabled to examine for these organs they were found to be in a state similar to that in the adult.

2. *Balænoptera sibbaldii* (Gray).

The only fœtus examined of this species was a young female about 8 feet long. The mother was No. 3, Table III. The only points of

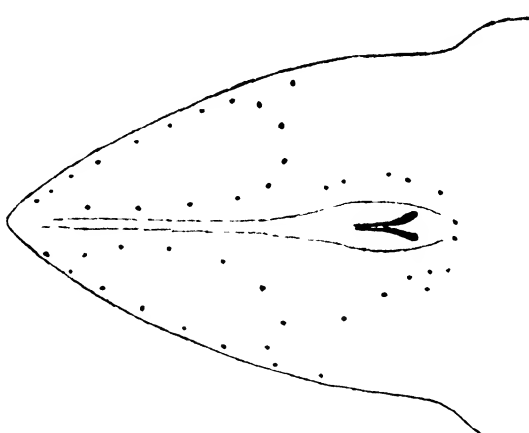


FIG. 5.—Dorsal Surface of Beak of *B. sibbaldii* (Fœtus), No. 3, showing hairs. (Approx. $\frac{1}{10}$).

interest noted in this specimen were the condition of the Organs of Jacobson, and the distribution of hairs on the upper part of the snout.

[47] Kukenthal, *op. cit.*, vol. ii., p. 285.

A *Organs of Jacobson* —In this specimen these were represented by a shallow depression only on the left side, while on the right side there was a short tube about 5 mm long, running just under the surface backwards from the hinder end of the depression.

B *Hairs on upper part of snout* —These were more numerous than in the adult, and were arranged in a slightly different way The actual relative positions of the hairs in this specimen are shown in fig 5.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Professor S. J. HICKSON (*Chairman*), Mr. E. S. GOODRICH (*Secretary*), Sir E RAY LANKESTER, Professor A. SEDGWICK, Professor W. C. McINTOSH, Dr. S. F. HARMER, Mr. G. P. BIDDER, Mr. W B. HARDY, *and* Professor A D WALLER, *appointed to aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples*

SINCE the last report of the Committee was written, Mr W O Redman King occupied the table until the end of August 1911, Hon Miss Mary Palk from November 5, 1911, until March 28, 1912; and Mr C H Martin from May 10 to May 21, 1912 Short reports of the work done by Mr Redman King and Mr C H Martin during their stay in Naples have been received and will be found below

During the past year the Zoology Organisation Committee of the British Association have made efforts to secure a permanent endowment for one or more British tables at the zoological station at Naples, but so far without success That Committee will continue its work in this matter during the coming session

The Naples Committee ask to be reappointed with a grant of 50*l*

Mr W O Redman King reports 'I occupied the British Association table at Naples for about eleven weeks during June, July, and August 1911 During this time I investigated the temperature coefficient of development of the sea-urchins *Sphærechinus* and *Arbacia*, over a range of temperature from 10° C to 30° C The coefficient for *Arbacia* turned out to be appreciably higher than that for *Sphærechinus*: the values were about 3 0 and 2 8 respectively The work has not yet been published, as I wish to amplify the results and extend the experiments to other forms '

Mr. C H Martin reports: 'I occupied the British Association table from May 11 till May 21 During this time I examined thirteen Boxboops, and I had an opportunity of confirming my former observation that the so-called *Trypanoplasma intestinalis* (Leger) is not really a Trypanoplasma, since it possesses three free flagella at its anterior end I was able to find a further series of division stages and (a point which is I believe of some importance) a series of stages which

I am forced to regard as representing the process of conjugation in this form. I hope to publish a full account of these stages, together with the observations I have made upon the other Intestinal Trypanoplasmas—viz., *Trypanoplasma congeri* from the stomach of the conger, and *Trypanoplasma ventriculi* (Keysselitz) from *Cyclopterus lumpus*—in a forthcoming paper.'

Secondary Sexual Characters in Birds.—Report of the Committee, consisting of Professor G. C. BOURNE (*Chairman*), Mr GEOFFREY SMITH (*Secretary*), Mr. E. S. GOODRICH, Dr W. T. CALMAN, *and* Dr. MARETT TIMS, *appointed to defray expenses connected with work on the Inheritance and Development of Secondary Sexual Characters in Birds. (Drawn up by the Secretary.)*

EXPERIMENTS and observations on the sexual characters of birds kept in my aviaries have been conducted on the following lines —

On Conditions determining the Growth and Development of the Comb.—Measurements have been made on the combs of nineteen control hens and nine experimentally treated birds, to ascertain whether the injection of testis-extract into the female had any effect in causing the fluctuations in size of the comb of the hen It was found that these fluctuations were independent of the experimental treatment and followed on the infiltration of fat into the comb which occurs during the egg-laying periods. Histological observations showed that the comb of the laying hen differed from that of the cock in containing a central core of connective tissue, which becomes loaded with fat at the reproductive periods These results are published in 'Q J M S,' vol 56, p. 591, and vol 57, p 45

On the Cause of Sterility in Hybrid Birds—An attempt was made to rear hybrids between the common pheasant and the jungle fowl, but the incubation of about sixty eggs resulted in the hatching of a single chick, which died owing to a cerebral hernia two days after hatching This chick on dissection proved to be a male, and the reproductive organs were in a perfectly normal condition for a chick of that age, showing no degenerative or retarded development Three hybrid male pigeons (hybrid between domestic dove and pigeon) were obtained from a pigeon-fancier. These birds were kept for about a year in my aviaries and were paired with female pigeons successfully, and the eggs were incubated in the normal manner by both parents In all cases the eggs were sterile. The three hybrids were killed and dissected, and their spermatozoa and testes, which on inspection appeared quite normal, were examined histologically On comparison with normal doves and pigeons, it was found that the great majority of the spermatozoa of the hybrids were twice the normal size, and this abnormality of size was traced to the fact that the second maturation division was entirely suppressed. The abnormality was traced further back to the first maturation division, where it was found that the

chromosomes, instead of forming the ordinary eight synaptic groups, were irregularly fragmented and scattered on the mitotic spindle, some of the chromatin masses being much smaller, others much larger, than the normal synaptic chromosomes Previous to this division it appeared that the spermatogonia in the testes were perfectly normal, so that we must ascribe the abnormality of the spermatozoa, and the consequent sterility of the hybrids, to the incapacity of the chromosomes derived from the two parents to form synaptic pairs These results will shortly be published in detail in the 'Q J M S'

Further observations on sterile hybrids are being made in the case of some birds presented by Mrs Haig Thomas, which have been kept for varying times in my aviaries and some of which are still alive Investigation of the sterile male shows similar features to those observed in the case of the pigeon-dove hybrids, but other observations on sterile females and another male hybrid are not complete. The sterile female hybrids show a partial assumption of cock's plumage, and this is probably correlated with the atrophy of the ovary, since I have collected within recent years several examples of this phenomenon, which will be described when the observations are complete

On the Inheritance of the Spurred Condition in the Domestic Hen —The object of this investigation is to attempt to discover if the inheritance of spurs in the hen could be explained on the same lines as the inheritance of the horns in horned breeds of ewe The difficulty of this breeding experiment lies in the fact that the birds have to be kept alive for at least a year, and for more to be on the safe side, before it can be settled whether a given female is going to develop spurs or not In consequence the experiment has not yet been going on long enough to speak with any certainty, but the following crosses have been made —

Normal ♂ × Spurred ♀ S

F_1 Normal Cock (Four Hens died)

F_1 Cock × P Spurred ♀ S

F_2 Six Normal Cocks and Five Non-spurred Females

Although the numbers are small, it was expected that half at least of the F_2 females would be spurred Now three of the F_2 cocks have been crossed with the F_2 females, and there are about twenty-five chicks being reared, but it is not yet possible to see if any of them will develop the spur. This should appear in six months' time

On the Inheritance of Extra-Toe in the Fowl.—Since the first male parent used in the above experiment showed the abnormality of extra-toe, crossings have been made to deal with the inheritance of this character Two distinct strains of extra-toe differing in the position and size of the extra-toe have been detected, and their inheritance is being tested against one another Crossings of what would be ordinarily called extracted recessives—*i e*, four-toed ♂ × four-toed ♀—have given about ten per cent of five-toed progeny An extracted four-toed hen of one strain of extra-toed race, crossed with a five-toed

cock of the other strain, has given a certain number of chicks with extra-toe of the type belonging to her own strain of extra-toe The experiment is still in progress

Feeding Habits of British Birds —Fourth Report of the Committee, consisting of Dr. A. E. SHIPLEY (*Chairman*), Mr. H. S. LEIGH (*Secretary*), Professors G H. CARPENTER, F. W. GAMBLE, S J HICKSON, J. ARTHUR THOMSON, *and* F. E. WEISS, Dr C GORDON HEWITT, *and* Messrs J. N. HALBERT, ROBERT NEWSTEAD, CLEMENT REID, A. G L. ROGERS, *and* F. V. THEOBALD, *appointed to investigate the Feeding Habits of British Birds by a study of the contents of the crops and gizzards of both adults and nestlings, and by collation of observational evidence, with the object of obtaining precise knowledge of the economic status of many of our commoner birds affecting rural science.*

THE investigation of the feeding habits of the rook, starling, and chaffinch has been continued during the past year

The progress of the work has been very much hindered owing to the fact that great uncertainties with regard to the financial and other arrangements have recently existed No fresh birds were received Some of the results obtained from the examination of the contents of 1,062 crops (218 rooks, 487 starlings, and 357 chaffinches) received in previous years are now being arranged and tabulated for the publication of an interim report, and it is hoped this will soon be ready In future the work of examining the crop-contents will be divided between the South-Eastern Agricultural College at Wye and the Victoria University of Manchester, and a grant of money has now been definitely promised from the Development Commissioners to enable this work to continue

It has been decided that only England and Wales shall be included in the new scheme, and that the Agricultural College at Wye shall receive birds obtained from correspondents in the southern, south-eastern, and south-midland counties, and Manchester University shall receive birds from the northern, north-western (including Wales), and north-midland counties The work of obtaining fresh correspondents will now be undertaken by the Board of Agriculture and Fisheries

The Zoology of the Sandwich Islands.—Twenty-second Report of the Committee, consisting of Dr F. DU CANE GODMAN (*Chairman*), Mr D SHARP (*Secretary*), Professor S J HICKSON, Dr P L. SCLATER, *and* Mr EDGAR A SMITH.

THE completion of the 'Fauna Hawaiiensis' (which work is the true report of this Committee) is now in the press, and the preface thereof summarises the operations of the Committee

Marine Laboratory, Plymouth.—Report of the Committee, consisting of Professor A. DENDY (*Chairman and Secretary*), Sir E. RAY LANKESTER, Professor A. SEDGWICK, Professor SYDNEY H. VINES, *and* Mr. E. S. GOODRICH, *appointed to nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.*

DURING the past year the table has been occupied for one month by Mr H M Fuchs, who reports as follows:—

'In the month during which I have occupied the British Association table this summer, I have continued an investigation into the hybridisation of Echinoids. A preliminary account of the inheritance of characters in hybrids between the three English species of *Echinus* was published last autumn in conjunction with Messrs Cresswell Shearer and Walter De Morgan [1] During the spring and summer of this year the experiments have been continued, especially with reference to the heredity in the sea-urchins after metamorphosis As the work is as yet incomplete, I do not wish to make a statement of results at present '

Zoology Organisation —Report of the Committee, consisting of Sir E RAY LANKESTER (*Chairman*), Professor S J HICKSON (*Secretary*), Professors G C. BOURNE, J COSSAR EWART, M HARTOG, W A HERDMAN, *and* J. GRAHAM KERR, Mr. O. H LATTER, Professor MINCHIN, Dr. P. C. MITCHELL, Professors E B POULTON *and* A SEDGWICK, *and* Dr. A. E. SHIPLEY.

DURING the past session the Committee have made an effort to place on a permanent basis the allocation of one or more tables at the zoological station at Naples for British subjects A letter was written by the Secretary and forwarded to the Chancellor of the Exchequer asking for consideration of the request that the Government should secure two tables for British subjects The reply to this letter was not favourable The Committee have now under consideration other proposals for achieving the same object.

In the early part of the year the Committee decided to take a census of the opinion of British zoologists on the question of the strict application of the law of priority in zoological nomenclature

A circular was prepared and zoologists were asked to sign one of the two following statements —

(*a*) The undersigned British Zoologists are of opinion that the Law of Priority as regards zoological nomenclature should be strictly applied in all cases

(*b*) The undersigned British Zoologists protest against the strict application of the Law of Priority in all cases, and desire that

[1] Journ. M.B.A , vol ix.

the International Commission on Zoological Nomenclature should protest against any change in the generally used names of the most important genera and species.

On July 22 of this year 108 of the slips had been returned to the Secretary, and it was found that twenty-six zoologists had signed the statement (*a*) in favour of the strict application of the Law of Priority, and eighty-two had signed the statement (*b*) protesting against the strict application of the Law of Priority. Of those who signed statement (*a*), five proposed certain amendments to the form in which it was sent out, and of those who signed statement (*b*), four proposed verbal alterations

As the funds at the disposal of the Committee were becoming exhausted, the zoologists on the register were invited to send a small subscription to the Secretary This invitation met with a welcome response, and the Committee have now in hand a sum of over 26*l* for the purposes of the Organisation

The Committee ask to be reappointed

Natural History, &c., of the Isle of Wight.—Report of the Committee, consisting of Mr. CLEMENT REID (*Chairman*), Professor J. L. MYRES (*Secretary*), Mr. O. G. S. CRAWFORD, Mr. W. DALE, Professor E. B. POULTON, *and* Dr A B. RENDLE, *appointed to co-operate with local bodies in acquiring and arranging collections to illustrate the Natural History, Geography, and Antiquities of the Isle of Wight*

THE Committee report that some progress has already been made in acquiring and arranging collections The original proposal which was put forward in the island, and discussed when the Committee was appointed at the Portsmouth Meeting, was to transfer to the Carisbrooke Castle Museum the whole of the collections formerly belonging to the Newport Literary Society, and so to make Carisbrooke the centre for all departments of study But it has been represented to the Committee that it would be more convenient to those who use the collections that separate provision should be made for the Archæological and for the Natural History Collections—depositing the former at Carisbrooke Castle Museum, as was originally proposed, and developing further a proposal (which is supported by some of the geologists and naturalists of the island) to establish a Natural History Museum in a municipal building shortly to be acquired by the Local Authority at Shanklin

The archæological collections have accordingly been transferred to Carisbrooke, by agreement between the Newport Literary Society and the Governor of the Isle of Wight, H R H. Princess Henry of Battenberg The cost of repairing and setting in order has been met from the British Association's grant and by the sale of a few objects which had no bearing upon the archæology of the island Additional museum accommodation has been generously provided by Her Royal Highness

in the castle, and the collections are under the direct supervision of the Deputy Governor, Mr F Hay Newton, M V O , with Mr. O G S Crawford as honorary curator As was confidently expected when the proposal for an island museum was first put forward, other collections are already being presented or offered on loan A beginning has been made with the arrangement of a Bronze Age room; and a public appeal has been made in the island for subscriptions to furnish this and the proposed Stone Age room and Iron Age and Roman room

Meanwhile the Committee have been in correspondence with geologists and naturalists in the island in regard to the Natural History collections, and expect to be able to announce a working scheme before long They therefore ask to be reappointed, with the unexpended balance of their grant

---

Gaseous Explosions —Fifth Report of the Committee, consisting of Sir W. H. PREECE (*Chairman*), Dr DUGALD CLERK *and* Professor BERTRAM HOPKINSON (*Joint Secretaries*), Professors BONE, BURSTALL, CALLENDAR, COKER, DALBY, *and* DIXON, Dr GLAZEBROOK, Professors PETAVEL, SMITHELLS, *and* WATSON, Dr HARKER, Lieut -Colonel HOLDEN, Captain SANKEY, Mr. D. L. CHAPMAN, *and* Mr H E WIMPERIS, *appointed for the Investigation of Gaseous Explosions, with special reference to Temperature.*

FIVE meetings of the Committee have been held, one at the Central Technical College, when Professors Callendar and Dalby were good enough to show the members of the Committee the apparatus used in their experiments on gas-engines, and four (by the kindness of Dr. Dugald Clerk) at 57-58 Lincoln's Inn Fields In accordance with their previous practice, notes dealing with their current work have been presented for discussion by members of the Committee, as follows.—

No 21	Measurements of Turbulence caused by Suction in the Gas engine	B Hopkinson
No 22	Rate of Flow of Air through a Round Orifice	W Watson
No 23	Experiments on Some Conditions which cause great Variation in the Rate of Inflammation within the Gas-engine Cylinder	Dugald Clerk
No 24.	Effect of Turbulence on Heat Flow .	Dugald Clerk
No. 25.	The Effect of Turbulence on Rate of Ignition and of Heat Loss	B Hopkinson
No. 26.	The Flow of Heat from a Charge of Air subject to Cyclical Variations of State in the Cylinder of a Gas-engine, and the Comparison of the Temperature Readings of a Platinum Thermometer with the Temperature computed from the Pressure-volume Diagram . . .	W. E Dalby

During the session 1911-12 the experimental work by members of the Committee has been continued, and some of it has been brought to a conclusion Much of this work has consisted of measurements of radiation and of turbulence in a gaseous explosion, and W T David, a pupil of Professor Hopkinson, has published an important paper in

the 'Philosophical Transactions of the Royal Society' dealing with the first of these matters. The rest of this work has not yet been published, but an abstract of the results obtained is given in the body of this Report. Professor Dalby has continued his measurements of the suction temperature in gas-engines and of the gas temperature reached in compressing and expanding air. Professor Watson has read a paper on the measurement of air-flow by means of an orifice, the results of which make available for use an accurate and simple method of measuring the supply of air to a gas-engine, and will therefore be of great value to those engaged on experimental work on such engines.

In this Report the Committee propose to give a short review of the present state of knowledge with regard to the heat-flow from the working substance of a gas-engine into the cylinder walls. It is unnecessary to insist on the importance to practical designers of this side of the theory of internal combustion engines. It is now fully recognised that a great part of the difficulties experienced in the construction and working of these engines is ultimately due to heat-flow, and the subject has been brought into special prominence in recent years by the introduction of large cylinders in which these difficulties have only partially been overcome.

The rate of flow of heat from the gas to any part of the walls at each instant of time depends upon the then state of the gas as regards temperature, density, and motion, and also on the temperature and condition of the wall surface. It differs widely at different points of the expansion stroke, being far greater just after firing, when the gas is at a high temperature and highly compressed, than towards the end of expansion. There will, however, be a certain mean rate of heat-flow into any patch of the cylinder walls, and heat must be conducted from that patch on the whole as fast as it goes in. In order that the heat may be conducted away at the required rate there must be a certain temperature gradient in the metal, and there will be a corresponding mean surface temperature. Superposed on the mean surface temperature are variations due to the varying rate of heat-flow at different parts of the cycle. The thermal conductivity and capacity for heat of cast iron are, however, so large that these variations on a clean metal surface must be small—a conclusion which has been verified by Coker, who found a maximum cyclical change of but 7° C. at a depth of 0.015 inch in the wall of the combustion chamber of an engine running at 240 revolutions per minute. If the metal surface is not clean the variation at the surface of the carbon or other deposit may be much greater.

The important practical question is the mean rate at which heat goes into each part of the surface, and the resulting mean distribution of temperature. The chief problem in designing large gas-engines is to control the mean temperature distribution by water-jacketing or otherwise in such a way that the metal does not get overstrained by unequal expansion nor reach a temperature sufficient to ignite the gas. The temperature gradient necessary to sustain the flow of heat from the inside of a combustion chamber to the external water is not likely to exceed 50° C. per inch. At places where the metal is not thick and

effective external circulation of water is possible, cooling does not present great difficulty, but at places which are not near to the cooling water, so that the heat has to travel a long way, the temperature must be high to give the necessary gradient. Thus the central portion of the head of an ordinary flat-faced piston if not water-cooled gets very hot, reaching a temperature of perhaps 600° C. in a four-cycle engine of 24 inches bore. The piston expands considerably in consequence, the expansion being greater at the centre than at the edge which is accordingly put into tension. In larger cylinders the stresses in the piston set up by unequal heating, and the danger of pre-ignition arising from the hot metal, necessitate the cooling of this part by the circulation of oil or water. Even then the great thickness of metal in certain portions of the combustion chamber, and the difficulty of keeping the water flowing properly in every corner, may cause high local temperatures.

The heat carried away by the cooling water and by radiation is the total given to every part of the walls, and its measurement gives no information on the important question of the manner in which the flow is distributed over the walls. It is certain, however, that the greater part of the heat-flow in a cycle occurs in a comparatively short time just after the moment of ignition, and passes therefore into the surface of the combustion chamber and valves and into the face of the piston. But little goes into the barrel of the cylinder, which is not uncovered until the density and temperature of the gases have fallen. That this must be so is obvious, but the magnitude of the effect is perhaps not generally recognised. Dugald Clerk found in his experiments on the compression and expansion of flame[1] that the average heat-flow per square foot per second in the first three-tenths of the stroke is three times that of the average over the whole stroke for equal temperature differences, and he calculates that the actual rate of heat-flow in the first three-tenths is six times that of the whole stroke in ordinary gas-engines working at full load. This estimate, however, does not include loss due to radiation before maximum temperature. In the actual firing and expansion stroke of a gas-engine the difference must be even more when radiation and other losses incurred before maximum temperature are included, and it is probable that in discussing the problem of cooling the metal it is a sufficiently good approximation to neglect the heat-flow into the outer half of the barrel altogether. Professor Hopkinson informs the Committee that he has worked a gas-engine cylinder of over 30 inches diameter in which there was no water circulation round the barrel at all. The whole of the heat passing into the barrel was in this case removed either by radiation or by conduction into the piston, nor was the cooling which was applied to the piston much more than that found necessary on other parts of the walls of the combustion chamber. In small engines with uncooled pistons the water-jacket round the barrel is necessary to keep the piston cool.

In the scientific analysis of gas-engine phenomena the facts stated in the last paragraph are important because they show that the heat-

[1] *Proc. Roy. Soc.*, A., vol. 77 (1906), p. 500.

flow is not much different from that which would occur in a closed vessel of invariable volume having the form and size of the combustion chamber, the mixture fired having of course the same composition, density, movements, &c , as in the engine Some allowance must be made for the fall of temperature and density which occurs in the initial stages of the expansion in the engine, but this will be of the nature of a correction and will not affect the value of the general conclusions as to the effect of the various factors in heat-flow which may be drawn from closed-vessel experiments

The Factors in Heat-flow

1 *The State of the Walls* —The loss of heat following a gaseous explosion in a confined space depends partly on the state of the gas and partly on the state of the walls of the enclosure Dealing first with the walls, it is obvious that the higher the surface temperature the less rapid will be the flow of heat, which (generally speaking) depends on the difference of temperature between the gas and the surface If the metal surface be clean the surface temperature cannot rise by more than an insignificant percentage of the temperature difference, but if it be coated with a non-conducting layer the exposed surface may be heated by the first rush of heat after ignition to such an extent as materially to check the subsequent flow For instance, Hopkinson found that a layer of brown paper $\frac{8}{1000}$ inch thick pasted inside an explosion vessel of 1 cubic foot capacity would reduce the rate of heat-flow in the first tenth of a second following maximum pressure by more than 30 per cent [2] The surface of the paper was not charred, but it must for an instant have reached a temperature of several hundred degrees Centigrade in order to produce such a result This shows that a badly conducting deposit of carbon in a gas-engine may materially reduce heat-flow Since the high surface temperature occurs just after explosion, it will not necessarily cause pre-ignition, though of course if the mean temperature be high, so that the surface remains red-hot throughout the cycle, it will have that effect

2 *Radiation from the Gas* —Of more scientific, though perhaps of less practical, interest is the reduction in heat-loss which is found when the walls are highly polished This is due to the fact that radiation is an important, if not the principal, agent in the transfer of heat from the gas to the metal This matter was dealt with in the third Report of the Committee, and it is unnecessary to recapitulate the results there given It has however been carried a good deal further by the researches of W T David, who has investigated the relation between the amount of the radiation and the mean temperature of the gas [3] He finds that the rate of loss from this cause varies roughly as the fourth power of the absolute temperature Thus the products of exploding a 15 per cent mixture of coal-gas and air in a cylindrical vessel 1 foot by 1 foot radiate about 5 gramme calories per square centimetre per second when the absolute temperature is 2100° C (maximum

[2] See *Engineering*, September 11, 1908, p 328
[3] *Phil Trans Roy Soc* , A , vol 211, p 375

pressure), but a tenth of a second later, when the temperature has fallen to 1700° C., the radiation is only half as great.

In a closed-vessel explosion the rate of heat-flow diminishes with very great rapidity as the gas cools down after ignition. Thus Hopkinson found that the products of igniting a mixture of coal-gas and air in a closed cylindrical vessel 1 foot by 1 foot lost heat at the rate of 10 gramme calories per square centimetre per second at the moment of maximum pressure, when the temperature was 1760° C. One-fifth of a second later, when the mean temperature was 1300° C., the rate of heat-loss was reduced to 3½ calories, or only one-third of its value at maximum temperature.[4] One cause of this is the fact that when the flame first touches the walls the heat is drawn almost wholly from the surface layer of gas in contact with them, and the flow is at first extremely rapid. This surface layer soon parts with its heat, and further supplies have to be drawn from the inner portions of the gas, the cool surface layer now acting as heat insulation. But it is probable that the rapid reduction in radiation as the temperature falls is quite as important a factor in this phenomenon. In the gas-engine it is, of course, accentuated by the reduction of temperature consequent on expansion. The closed-vessel experiments lend confirmation to the view already expressed, that in the gas-engine the rate of heat-flow per unit of area has fallen to a comparatively small value when the piston has moved a short distance out on the expansion stroke.

An important practical consequence of radiation is the greatly increased loss of heat which occurs when the mean pressure in an engine is increased by increasing the strength of the mixture. The jacket loss and the metal temperatures are raised in a much greater proportion than the fuel consumption, and the efficiency is diminished. In very large engines this sets a fairly sharp limit to the possible output, which is as a rule considerably less than the maximum of which the engine would be capable if it were given all the fuel that it could take. If the load be in excess of this limit the engine overheats rapidly in consequence of the greatly increased heat-flow.

3. *The Effect of Cylinder Dimensions on Heat-flow.*—At first sight it might appear that heat-flow is a surface phenomenon—that is, the number of calories per square centimetre per second passing into the walls of an engine or explosion vessel containing a gas at a given temperature and density should be independent of the volume. This view, which is rather widely held, is, however, certainly erroneous, and probably to a considerable amount. The effect of radiation is necessarily to make the heat-loss per unit area from a large volume greater than that from a small volume, because the walls receive radiation from the inner layers as well as from the portions nearer to them. At some depth, of course, the radiation will cease to be sensible, and when that has been reached the radiation from the whole mass will not be increased by further increasing its volume. The experiments of David, to which reference has been made, show that the transparency of the products of an explosion while still at a high temperature is very great,

[4] *Proc. Roy. Soc.*, A., vol. 79, p. 138.

and lead to the conclusion that the heat-loss per unit area from a mass of glowing gas would go on increasing with the volume of the mass until that volume is comparable with the largest sizes of gas-engine cylinder now made. David found that the radiation after an explosion in a cylindrical vessel 1 foot by 1 foot was nearly twice as great when the walls of the vessel were highly polished as when they were black. The effect of completely polishing the interior of a vessel is, so far as radiation is concerned, much the same as greatly enlarging the volume of enclosed gas, so that this experiment gives an idea how far the heat-loss from the gas in a cylinder 1 foot in diameter falls short of that in a very large cylinder. It is quite clear that in a 12-inch cylinder the limit of size beyond which heat-loss per square foot does not increase is far from having been reached.

One practical aspect of this question is the relation between size and thermal efficiency. This was fully discussed by Callendar in a paper read before the Institution of Automobile Engineers in 1907,[5] who pointed out the probability that some part of the radiation loss was proportional to the volume. If heat-loss were simply a question of the surface exposed the percentage losses in similar engines should be reduced in proportion to the linear dimensions, and there should be a corresponding increase in efficiency. But in so far as heat-flow increases with the volume, the efficiency of large and small engines will become more nearly the same. Of even greater importance practically is the absolute amount of heat-flow per square foot, since it is this which determines the internal temperatures and so sets a limit to the output of the engine. The results cited show broadly that this quantity must be considerably greater in an engine of say 3-feet bore than in one whose cylinder diameter is only 1 foot, and that the difficulty of designing and working the first is not alone due to the greater thickness of metal, but also to the greater heat-flow.

4. *The Effect of Density.*—The density of the gas in a gas-engine explosion is from four to seven times that of the atmosphere. In the Diesel engine it is, of course, very much greater. The effect of this factor is greatly to increase the heat-flow as compared with an ordinary closed-vessel explosion, where the density is that of the atmosphere and the vessel similar in size and shape to the combustion chamber. A rough notion of the magnitude of this effect can be obtained by comparisons of the jacket-loss in a gas-engine when the total quantity of combustible mixture is altered by throttling or otherwise, the composition remaining the same. It has been found that the total heat carried away from the jackets increases with the quantity of mixture, but not quite in proportion thereto. A similar result is obtained from closed-vessel explosions; it is found that the pressure after firing a mixture of given composition falls relatively less rapidly when the pressure before explosion is higher, but the absolute amount of heat-loss in a given time is greater.[6] The quantitative relation between heat-

[5] *Proc. Inst. Aut. Eng.*, April 1907.

[6] *The Gas, Oil, and Petrol Engine*, by Dugald Clerk, vol. i., chap. vii. (Longmans, 1910.)

flow and density seems to be complicated and dependent upon the size and shape of the enclosure. In one experiment on a gas-engine of $11\frac{1}{2}$ inches bore, the jacket loss varied as $(\text{density})^{0 \cdot 9}$ when the density at the moment of the explosion was varied from three times atmospheric to about six times.[7] After an explosion in a cylindrical vessel 1 foot by 1 foot, the absolute rate of heat-loss is roughly twice as great when the initial pressure is $1\frac{1}{2}$ atmosphere, as when it is $\frac{1}{2}$ atmosphere, corresponding to the relation[8] $(\text{density})^{0 \cdot 6}$.

The relation between heat-loss and density in an explosion vessel is dependent upon two factors—namely, radiation and direct surface-loss by convection and conduction. To a first approximation it may be expected that the heat radiated from a given mass of gas at a given temperature will be independent of the volume which it occupies because the number of radiating molecules is the same. Thus, to obtain from closed-vessel experiments at atmospheric density an estimate of radiation in a gas-engine in which the ratio of compression is, say, 5, it would be necessary to experiment with a vessel of the same shape as the combustion chamber, but of five times the volume. From the work of David, however, it would appear that the radiation increases slightly with the density, so that the flame in the gas-engine would radiate a little more heat than an equal amount of gas at atmospheric density in the closed vessel.[9] The effect of the other element in heat-loss—namely, convection currents—is probably more affected by the density than is radiation, and may perhaps increase in proportion thereto. The heat-carrying power of the gas depends upon its capacity for heat per unit-volume, and this increases in proportion with the density. Thus it may be expected that the amount of heat transferred to the walls from the interior by a given amount of bodily movement of the gas will increase more or less in proportion to the density. It is therefore to be expected that the combined effect of these two factors, radiation and convection, will be to make heat-loss in a vessel of given form increase according to some fractional power of the density.

The most important practical question connected with the relation between density and heat-loss is the effect of degree of compression on the working and efficiency of gas-engines. To put the matter in its simplest form we may suppose that the engine has a cylindrical combustion space and flat-headed piston, so that the enclosure containing the gas at the moment of firing is a cylinder. The length of this cylinder will in most cases be a fraction of the diameter, the ratio of diameter to length being of the same order as the compression ratio of the engine. The problem, then, is to determine how the amount and distribution of heat-loss to the walls is altered when the compression ratio of the engine is changed, say, by lengthening the connecting rod. In the ordinary case of a fairly high compression ratio, the effect of this alteration will be to reduce the length of the

[7] *Proc. Inst. Civil Eng.*, vol. 176, p. 234.
[8] David, *loc. cit.*
[9] David, *loc. cit.*, p. 404.

cylindrical combustion space without changing its diameter, and to keep the mass of gas confined therein substantially constant so that the density goes up in inverse proportion to the length of the space. At the same time there will be a small rise in the temperature of the fired mixture consequent on the higher temperature before firing. This, however, would not be very much, amounting to about 100° C. for an increase in compression ratio from 4 to 6.

The average heat-loss per square foot to the surface will increase, but not in proportion to the density. On the other hand, the area over which that loss is distributed is reduced, but again in a considerably less proportion than the density. For instance, with an engine of equal stroke bore ratio, having a cylindrical combustion chamber, the result of increasing the compression ratio from 4 to 6 will be to reduce the surface of the combustion chamber by nearly 16 per cent. The density is, of course, increased 50 per cent., and if the heat-loss increases in a greater ratio than the square root of the density, which is almost certainly the case, the effect of this increase of compression would be to increase the total heat-loss, and therefore to diminish the efficiency of the engine relative to the air standard. This in the case supposed would not, of course, lead to any reduction in actual efficiency, because the greater heat-loss would be more than counterbalanced by the increase in the efficiency due to increased expansion. But it is clear that if the process were carried sufficiently far the absolute efficiency might also be reduced. Some approach to this state of things was found by Burstall when the compression exceeded about 7.[10]

The conclusion gained from practical experience, that there is a point beyond which it will not pay to increase the compression in the gas-engine, is therefore in full accord with the results of laboratory experiments on the relation between density and heat-flow. Not only is there a point beyond which increasing compression is not followed by an increase in efficiency, but before that point is reached the flow of heat per unit area is increased to an amount at which trouble will begin to arise on account of the difficulty of cooling. It is sometimes supposed that the difficulties which arise from pre-ignition when the compression is increased too far are due in some way to the rise of temperature of the gas consequent on the high adiabatic compression. It is very improbable, however, that this has much to do with the matter. The real cause of pre-ignition is the overheating of some part of the interior surface of the metal or of a deposit thereon, due to excessive heat-flow following an increased density. If the metal could be kept clean and cool, compression could be carried to very much higher values than are now used in practice without any danger of pre-ignition.

The effect of increasing density on heat-loss is, however, a matter on which further experimental evidence is needed. A comparison of the rates of loss after explosions in a series of cylinders of the same

[10] *Proc. Inst. Mech. Eng.*, 1908, p. 5. See also Professor Callendar's remarks in discussion on paper by Dr. Watson, *Proc. Inst. Aut. Eng.*, vol. iii., p. 457, where the limit of advantageous compression in the petrol motor is estimated as 4 to 5.

diameter but of different lengths, the density of the mixture fired being varied in inverse proportion to the length (so as to keep the total quantity constant), would be of great interest Such a comparison would throw direct light on the heat-flow in an actual gas-engine if among the cylinders tried were some in which the length was a fraction—say, one-sixth to one-third—of the diameter In many gas-engines the shape of the combustion space is approximately of this character

5 *Turbulence* —During the suction stroke of a gas-engine, or during the period of injection in an engine charged from a separate compressor, the mixture of gas and air which is subsequently to be exploded enters the engine through the valves or ports at a high velocity, so that the gas within the cylinder is in a state of eddying or turbulent motion This motion gradually dies away after the valves are closed, but will persist for some time during the compression stroke, so that at the moment of explosion there may still be a good deal of turbulence In consequence of this motion of the gas the convection of heat will go on more rapidly, and what may be called the 'effective conductivity' of the gas will be increased

Perhaps the most obvious direction in which to look for the effects of turbulence in gas-engines is the relation between speed and fuel economy, and this aspect of the matter has been discussed by Callendar, Lanchester, and others On the one hand it may be expected that the longer the time taken over the operations of compression and expansion the more heat, other things being the same, will pass into the walls during that period As against this must be set the consideration that, with a given valve opening, slow speed means less turbulence, first, because the velocity of entry of the gas is less, and second, because the time available for the resulting turbulence to die out under the influence of viscosity is longer Reduction of speed therefore means less effective conductivity, and it is even conceivable that on this account the heat-flow per cycle may be less and the fuel economy greater at the lower speed The effect of heat-flow upon economy is not very marked, and it is therefore not surprising that no decisive verdict has yet been pronounced on the relation between economy and speed There is no doubt that, given satisfactory ignition, economy is somewhat improved by increasing the speed, but the relation between these two things has not been so precisely determined as to permit a conclusion to be drawn about the part played by turbulence, nor in view of the complication of the question does it seem likely that much information can be derived from this source A more promising line of inquiry would be a direct measurement of jacket-losses at different speeds The Committee are not aware that any very accurate measurements of jacket-loss at different speeds, other conditions being kept rigorously the same, have ever been undertaken From some rather rough measurements of this character made by various members of the Committee, it appears that the heat-loss per cycle does undoubtedly diminish with increase of speed, but not in proportion thereto

The complete elucidation of the part played by turbulence in the

working of a gas-engine seems, however, to require more direct methods of investigation than the ordinary tests During the past year Dugald Clerk has applied his method of indicating the engine with tripped valves, so as to obtain a 'zigzag' diagram, to the investigation of this point During the first expansion line in such a diagram there is present the normal amount of turbulence which obtains in the ordinary working of the engine, during the second and later expansions of the 'zigzag' the turbulence has practically died out We have here obviously a method of considerable delicacy for detecting and measuring the effect of turbulence in causing heat-loss on the expansion line Clerk has found that in the compression and expansion of air or carbon dioxide without firing, the engine being simply motored

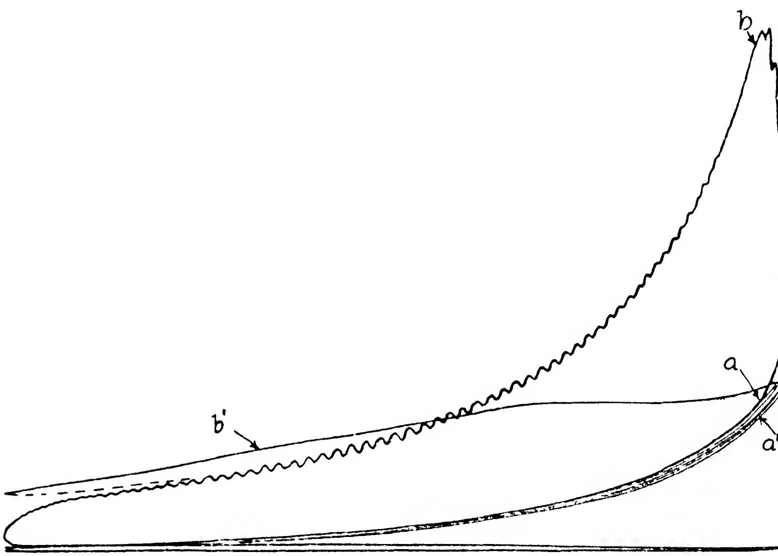


FIG. 1.—Ordinary ignition, *a* to *b*, takes 0·037 second, trapped ignition on third compression, line *a'* to *b'* takes 0 092 second, mixture in both cases, 1 vol. gas, 9 3 vols air and other gases.

round, the rate of heat-loss at a given temperature is greater in the first compression after drawing in the charge than in the subsequent compressions

For the purpose of studying by this method the effect of turbulence on heat-loss in the ordinary working stroke of a gas-engine, Clerk tried the experiment of drawing in a combustible charge into the engine in the ordinary way and then tripping the valves and compressing and expanding this charge for one or two revolutions before firing By this means the turbulence which, in the ordinary method of working, persists till the moment of firing was given time to die away It was expected that a comparison of an expansion line

obtained in this manner with that following a normal ignition would show the effect of turbulence on heat-loss While the experiment did not give any very clear indication on this point, it was the means of bringing to light a matter of perhaps greater importance Clerk found that the result of damping down the turbulence was to retard the rate of inflammation of the gas to a very remarkable extent, so that the character of the diagram was completely altered Two of Clerk's diagrams are reproduced (see figs 1 and 2), from an inspection of which the importance of this point in the working of gas-engines will be appreciated If ignition be delayed until the combustible mixture taken into the engine has been compressed and expanded twice and then again compressed, the period of inflammation is about two

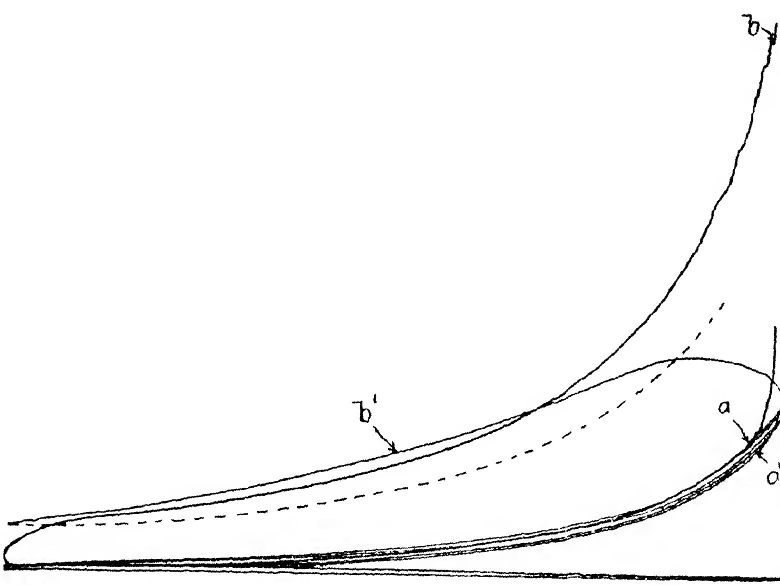


FIG. 2.—Ordinary ignition, a to b, takes 0 033 second, trapped ignition on third compression, line a' to b' takes 0 078 second, mixture in both cases, 1 vol. gas, 9·3 vols. air and other gases.

and a half times that of a normal ignition in which the gases have some turbulent motion The diagrams shown, figs 1 and 2, were taken by an optical indicator from an engine of 9 inches diameter cylinder and 17 inches stroke when running under full load at 180 revolutions per minute The engine was fitted with two electric igniters, one operating at the charge inlet-valve at the back of the combustion chamber, and the other operating at the side of the cylinder close to the piston In fig 1 the back electrical ignition was used, and in fig 2 the side igniter was in operation It has been noticed more than once that the period of inflammation in the gas-engine is considerably less than that obtaining in an explosion of a similar mixture in a closed

vessel of the size of the combustion chamber, and it must have occurred to many that, were it not for this fact, it would hardly be possible to work internal combustion engines at reasonably high speeds because the ignition would be too slow It now appears that this is wholly, or almost wholly, due to the fact that the gas in the engine is in turbulent motion.

Simultaneously with the experiments by Dugald Clerk, described in the last paragraph, Professor Hopkinson (with the assistance of his pupils, Messrs Miley and Peache) carried out some measurements of the effect of turbulence on heat-loss and inflammation phenomena in a closed-vessel explosion A cylindrical vessel, 1 foot in diameter by 1 foot long, was used and was lined with copper strip, the rate of heat-loss being measured by a record of the rise of electrical resistance of this strip A small fan was mounted in the centre of the vessel and comparisons were made of the result of exploding the same mixture, first with the fan at rest, and second when the fan was driven at a speed of several thousand revolutions per minute. These experiments also showed the great increase in speed of inflammation consequent on the motion of the gas Taking a mixture of 10 per cent of coal-gas and 90 per cent of air, the time from ignition to maximum pressure with the gas at rest is about 0 13 second, with the fan running at 2,000 revolutions per minute this time was reduced to 0 03 second, and at a speed of 4,500 revolutions per minute to 0 02 second The effect on heat-flow was also very marked At maximum pressure, with a 10 per cent mixture, the rate of flow of heat was approximately doubled when the fan was running at a speed of 4,500 revolutions per minute, the mean temperature of the gas in the two cases being the same (about 1600° C) It is interesting, however, to note that at the higher temperatures reached with a 15 per cent mixture—say at 2000° C —the heat-flow from the gas was not materially altered by the turbulent motion produced by the fan This is doubtless due to the fact that at such temperatures radiation is an important agent in the transfer of heat, and this would probably be unaffected by the motion of the gas

For the application of the results obtained with the closed vessel and the fan to the gas-engine, it is necessary to get some measure of the amount of turbulence remaining in the latter at the end of the compression stroke Mr H J Swain, under the direction of Professor Hopkinson, has made some measurements during the past year bearing upon this point It is hoped that full details of these experiments, and of those cited above, will be published in the course of the next few months, and the results only need be given here The method used was to determine the rate of loss of heat from a platinum wire mounted in the combustion chamber of a gas-engine, the wire being heated by an electric current Within moderate limits of temperature the heat-loss from such a wire is proportional to the temperature difference between it and the surrounding gas The ratio between heat-loss and temperature difference is a measure of the effective conductivity of the gas, and depends upon its temperature, density, and state of motion If the first two factors are the same, then the effective conductivity

depends only upon the state of motion, and may be taken as a measure of its amount. The wire was mounted in the combustion space of an engine of 7 inches bore and 15 inches stroke, which was motored round so as to compress and expand charges of air, the gas supply being cut off, and comparative measurements of effective conductivity at the top of compression were made first with the engine valves working in the ordinary way, and second with the valves closed, so that the same charge of air was continually compressed and expanded, and there was therefore no turbulence resulting from suction. It was found that at 240 revolutions per minute the conductivity was more than 60 per cent. greater in the first case than in the second, while at 60 revolutions per minute the difference was only about 20 per cent. In these comparative experiments the temperature and density of the gas were the same, and the difference could only be due to the motion. From measurements of the heat-loss from a similar wire in the closed vessel, Hopkinson infers that the motion of the gas with a fan speed of 2,500 revolutions per minute is probably considerably greater than that obtaining in the gas-engine. At this speed the heat-flow at a temperature of 1600° C. or over is increased by an amount of the order of 25 per cent., and, while it is certain that turbulence is responsible for some increase of heat-flow in the gas-engine, it is improbable that this is such as materially to affect the thermal efficiency, though it is of importance in the problem of cooling. The great influence of this factor on this manner of inflammation which has been disclosed by these experiments of Clerk, and of Hopkinson also, makes the subject worthy of more detailed investigation.

The Committee consider that their work can be continued with advantage, and they therefore recommend that they be reappointed. Out of the grant of 60*l.* allotted to the Committee at the Portsmouth Meeting, 45*l.* has been expended in assisting individual members with their experimental work. The Committee are of opinion that the Association grant would be better applied if the whole of the money could be assigned to one laboratory, where experiments having a direct bearing on the work of the Committee could be carried out. Arrangements with this object are under consideration and will, it is expected, be concluded before the meeting of the Association. In these circumstances the Committee feel justified in asking for a grant of 100*l.*

Artificial Islands in the Lochs of the Highlands of Scotland.—Second Report of the Committee, consisting of Dr. R. MUNRO (*Chairman*), Professor J. L. MYRES (*Secretary*), *and* Professors T. H. BRYCE, W. BOYD DAWKINS, *and* W. RIDGEWAY, *appointed to investigate and ascertain the Distribution thereof.*

THE Committee have received the following report from Dom F. Odo Blundell, of St. Benedict's Abbey, Fort Augustus, in continuation of the memorandum printed in the First Report. Fresh information still

comes in from many quarters, and the Committee ask to be reappointed with the balance of last year's grant

APPENDIX

Report from Dom F Odo Blundell, *O S B*

The subject of artificial islands was first brought to my notice by Mr Thomas Wallace, F S A Scot, who suggested that Eilean Muireach, in Loch Ness, half a mile from Fort Augustus, might prove to be one of these islands A careful examination of it, a few months later, proved that Mr Wallace's surmise was quite correct, that the island stood on a floor of oak beams, and that wooden spars could be seen running into the rubble building, with large logs lying round the circumference of the island, apparently to keep the rubble from slipping down

The account of *Eilean Muireach* was well received by the Society of Antiquaries of Scotland, who voted a small sum to assist in investigating further examples of these artificial islands In the following summer eight further examples were investigated, of which I shall only give the briefest summary Loch Bruiach is situated about eight miles south-west of Beauly, at an elevation of nearly 1,000 feet The district is rich in prehistoric remains, including some hut circles half a mile to the east of the loch, a very complete stone circle in the village of Bruiach, and two other stone circles a quarter of a mile apart between Beaufort Castle and Belladrum Previous to my visit to the island Colonel the Hon Alastair Fraser had in 1880 cut a section downwards and had come upon large oaken beams lying one across the other His investigation was not, however, recorded as far as I can learn At the time of my visit the woodwork of the island was easily to be seen, as also the causeway to the shore In this example, as also in the preceding, large pieces of vitrified material are to be found, the existence of which on such islands is difficult to explain

In the Beauly Firth two islands were visited One is now almost obliterated by the works in connection with the harbour of Inverness, the other, known as *Cairn Dubh*, can generally be seen at low tide standing out a few feet above the long sandbank upon which it is situated In both these islands, but especially in the latter, numbers of oak beams have been found in recent years

The two islands in *Loch Moy* are of the greatest interest The larger, which is about two acres in extent, is no doubt natural It has, however, at different times been so fortified and strengthened as to give quite the appearance of being artificial On the occasion of a second visit to this island in June last, I was surprised to find a solid wall built up to strengthen the bank This wall was from five to six feet high and was faced with a great accumulation of soil, though as to whether this was placed there intentionally, or had accumulated during the course of ages, I could not determine This island was used almost down to modern times as the emergency residence of the Chiefs of the

clan Two hundred yards from the larger is the smaller island, known as *Eilean na Clach*—the stony island This only measures 30 feet by 20 feet, but is clearly artificial, and has always been recognised as such I do not, however, remember seeing any record of its being constructed of wood, as we proved it to be on the occasion of my last visit Wherever the iron head of the boat-hook was thrust into the foundation, the heavy thud of wood could be heard and even felt, whilst in places the wood was so decayed as to come up in small fragments at the point of the boat-hook, though we did not succeed in dislodging a whole beam

Of the two islands in *Loch Garry*, one shows no traces of wood, indeed the natural rock appears amongst the accumulation of stones, so that wooden support would have been unnecessary This island has the usual causeway leading to the shore, which, however, is difficult to trace in consequence of the loch having risen two or three feet owing to the accidental obstruction of the outlet though the falling of several large masses of rock The other island shows wood on all sides; at one point four beams can be seen concentrically converging from the centre of the island

Three miles east of the Loch Garry islands is that on *Loch Lundi*, which bears a close resemblance to the first-mentioned of them, and is very unlike the two natural islands in its immediate neighbourhood Perhaps these were too near the shore, or the water between them and the shore was too shallow to afford the protection desired Three miles south of Loch Lundi occur the two islands in *Loch Oich*

The last of the islands visited in 1909 was Keppoch's island in *Loch Treig*, where woodwork can be detected almost at every point This island, like many of the others described in this paper, was used as a rendezvous in the sixteenth and seventeenth centuries, but as there is no record of its having been constructed at so recent a period, it may be safely considered as belonging to the same date as the generality of these islands This is all the more probable when we remember how long traditions—such as that of the building of a fort, the committal of a murder, or other deed of blood—survive amongst the Gaelic-speaking population of these districts

The only island investigated by me in 1910 was the one in *Loch nan Eala*, near Arisaig This proved to be one of that class which are composed almost entirely of wood Some years ago Mr Astley, the proprietor, cut a mill-race from the loch to the sea, and the mill having fallen into disuse, the water of the loch was free to flow off to the sea, thus lowering the level of the loch fully three feet The island now stands in pasture land of somewhat boggy nature, and is only to be visited in fairly dry seasons At our investigation there were present Mr Nicholson, the present proprietor, and his sister, Dr Campbell, of Arisaig, and Mr Kerr, the factor All were greatly pleased to have such a good view of the island, which consists of long beams laid alongside each other and several layers deep Under the larger timber we found birch, which appeared to be a foot or more in depth It was interesting to note that the birchwood had the bark still on and looked

quite fresh When cut the wood had a pinkish colour, but this rapidly changed on exposure to the air to bluish-grey

I have dwelt in some detail on the foregoing examples partly to show the position of the investigation before the British Association Committee was appointed, and partly to give examples of each kind of island The labour of even a cursory visit to some of these islands is often so great that it was evident that one individual would not succeed in adding any great number to the list of already recorded examples There was also the fact that many of the islands were known to be artificial to persons living in their immediate neighbourhood, of which, nevertheless, there was no record It was to secure information regarding these that the British Association Committee issued a circular, of which four hundred and fifty copies have been sent out In almost all cases I wrote a note amplifying some points of the circular, and the number of replies received is in consequence most gratifying It will, I think, be best to consider the replies according to counties, working from south to north, and here I may mention that I have generally been glad to include in the list islands partly or wholly natural, when an artificial causeway proved that they had at some time been adapted for habitation Such causeways seem to prove the island-dwelling propensities of the inhabitants almost as much as do the completely artificial islands

Perthshire

Loch Moulin —Of this and the following examples Mr Hugh Mitchell, F S A Scot , sends very full reports He writes ' Loch Moulin—Moy-luine—the plain of the pool from which the present parish gets its name The loch adjoined the village of Moulin on the east, and was 600 yards long by 400 yards wide It was drained about 1770 The lake was shallow—probably not exceeding seven feet or less—with a peaty bottom A crannog, or artificial island, occupied the centre of the lake About 1320 a large castle was built on this crannog by Sir Neil Campbell, of Lochaw The castle has been a ruin since about 1550, but its walls, 6 feet thick, stand about 30 feet high. The ground shows that the crannog was formed of small stones from 10 lb to 40 lb in weight, probably resting on wood to prevent them sinking into the peat The foundation of the castle seems to rest on wood lying in the peat There is a sloping causeway on the shore, but it is only about 30 feet in length, and may have been where the boats landed from the castle There is a weem, or earth-house, in the bank near the site of the lake There was also a large stone circle, which was blasted eighty years ago for building-stone There are several standing stones, remains of circles, and numerous forts in the neighbourhood '

To the above may be added the statement in the Old Statistical Account written in 1793 that ' the vestiges of a causeway leading from the building to the nearest rising ground, a distance of 110 yards, are quite distinct ' This evidently refers to the opposite end of the causeway to that mentioned by Mr Mitchell, and establishes the fact of its existence fairly well.

Of the larger island on *Loch Tay* Mr. Mitchell writes: 'The Isle of Loch Tay is wholly formed of stones about 30 lb. to 50 lb. in weight. There is a long bank of gravel about 3 feet under the water, and the island has been formed by conveying stones from the shore and placing them on the gravel. The channel between the island and the shore is 12 feet deep except in one place, where the depth is only 4 feet, and this is causewayed all the way from the shore to the island.' Mr. Mitchell then gives the later history of the island, and adds regarding Loch Tay that there is a small island opposite Fernan, and another near Ardeonaig, whilst in Dr. Stuart's extremely valuable paper [1] mention is made of 'a small islet near the shore in the bay of Kenmore, on the south-east shore of Loch Tay, within 100 feet of the head of the loch.' Regarding these islands, Rev. J. B. Mackenzie, for forty years the much respected minister of Kenmore, writes as follows: 'In Loch Tay there are fully half a dozen of artificial islands known to me. I have roughly investigated all of these sufficiently to satisfy myself that they are artificial. They are of very varying size, down to simply a cairn of stones, only visible at very low lake.'

In *Loch Tummel* Mr. Mitchell investigated two islands. Of the larger, which measures 50 yards by 35 yards, he writes: 'This island stands in about 7 feet of water, but there is a deep channel between it and the shore. . . . The island is formed of stones, which seem to rest on trees. What looked like the ends of trees could be seen below the stones. The stones seem to have been carefully laid—almost as if built in courses—and average about 1 foot square.' He also describes a smaller island 25 feet in diameter, where 'the stones are placed closely together and have the appearance of being almost built into their present position. The loch having risen 2 feet in the last eighty years, has reduced the surface of the island.'

In *Loch Rannoch* also Mr. Mitchell investigated two islands. Of these he writes: 'In the centre of the loch at that part there is a bank of sand 200 feet in length and about 3 feet below the surface. At the south end of this bank, and just where the loch deepens, an island has been formed of stones evidently taken from the shore, as there are no stones on the sandbank. . . . Rannoch was part of the old parish of Killiechronan, which was merged in Fortingall at the Reformation. The church of Killiechronan has disappeared, but the burial ground is there, and inside the burial ground is an ancient burial cairn about 30 feet long by 6 feet high. There are no stone circles in the Rannoch district, but several single standing stones.'

Loch Earn presents an interesting example of how the woodwork, known by one person to exist in the foundations of an island, may escape the attention of another. In fact Dr. Munro, in his list, places the Loch Earn island amongst those in which no wood is discernible, and Mr. Alexander Porteous, the author of several books on the district, writes that as far as he knows there is no woodwork in the construction of the island. Dr. Richardson, M.D., North Berwick,

[1] *Proc. Soc. Ant. of Scot.*, 1865.

however, sends me the following extract from a rare pamphlet by Angus M'Diarmid, printed in Edinburgh in 1816. The English is probably some of the most extraordinary issued from any press whatever: 'An island, on that part of the said lake (Loch Earn) near Edinaple, which island, according to some affirmation, has been erected dexterous modelling its foundations were laid on timber on which they executed the operation so emphatically, that it were specious habitation, the primary idea of operating the said island for place of refuge to some of the inhabitants, to protect their precious goods from the insult of multitude of inhuman transactions

'Another island at the fit end, of the aforesaid lake, in anciently notoriously assaulters inhabited, wherein they were beheaded, in consequence of felonious conduct, by a valiant gentleman of Macnab, who on the execution of that purpose, has contribute the assistance of other three in bearing a boat from a far distance on their shoulder, over mountainous ground, in dead time of night By which intellectual plan, got in to the island, and forthwith finished the ravished inhabitants '

In the Report of last year I quoted the letter of Dr Th Johnston, M A , assistant to Sir John Murray, in the Lake Survey of Scotland, but the authority of the writer and the appositeness of his remarks makes it fitting that his opinion be again recorded here Dr Johnston suggested that the islands in *Loch Hoil*, *Loch Derculich*, and *Loch Essan* are artificial, and added 'In the majority of the lochs which I have visited, artificial islands exist, either as "islands" or more often as "cairns," more or less submerged The existence of causeways is frequent, and generally, as you know, they have a bend or turn in them, so that strangers or enemies would probably step off into deep water These islands have all a very similar structure and formation as far as surface inspection goes, and no doubt if you examined them in your diving dress you would find them much the same in construction as Cherry Island in Loch Ness '

Mr Alex Porteous thinks that at least one of the islands in *Loch Ochtertyre* is artificial

Stirlingshire

Loch Lomond offers examples very similar to Loch Tay, though at the time of writing sufficient information is scarcely available

In reply to my inquiry, Mr Robertson, of the Inversnaid Hotel, undertook to examine some of the cairns, which are situated five miles distant In order to facilitate his work I sent him a water-telescope On June 10 last he wrote 'I have now been able to examine the cairns which can well be seen in the present low state of the loch They occur in the bay where I have marked a red cross on the map enclosed, and immediately to the S of the point, called Rowchoish . . They are composed of large boulders, but are laid with such regularity that they appear to be artificial.'

Aberdeenshire

Aberdeenshire has so far added no fresh example to the four mentioned by Dr Munro, only one of which however is at present really an island, the other examples being now dry land, owing to drainage operations Of this one Mr Francis Diack, in his recent work on *Loch Kinnord*, gives a very full description, and arrives at the conclusion that the larger island may eventually be proved to be artificial, as well as the smaller one

Inverness-shire

In this county Dr Munro gives four examples To these we can now add those on Loch Ness, Loch Bruiach, the two in the Beauly Firth, two in Loch Garry and Loch Oich, one in Loch Lundi, Loch Treig, and Loch nan Eala These have already been described at the beginning of this Report On the mainland of Inverness-shire—that is excluding the Western Isles—nine other examples have been suggested, a total of twenty fresh examples That on *Loch Meikle* is described by Mr William Mackay, author of 'Urquhart and Glenmoriston,' and a well-known authority on Celtic antiquities He visited the island about 1876, and was informed 'that a causeway was known to run some distance from the shore, and then turn at right angles in order to deceive strangers' This island, which I visited last year, is now submerged, partly no doubt owing to the soft nature of the ground on which it is built, and partly owing to the outlet of the loch silting up and thus raising the level of the water

Loch Lundavra was suggested by Dr Miller and Mr Ewen-Watson, F S A Scot, as containing an artificial island, the tradition being that Macbeth was slain at his stronghold on this island

Loch Ruthven—A careful survey of the island in this loch was made by Mr Roderick McLean, C A, who also took excellent photographs The island is almost circular with a diameter of 57 feet, and stands about 4 feet above the average level of the loch Though no causeway was visible, the natives stated that on a clear day one could be seen leading to a peculiar hill or mound on the shore south of the island

Loch Arkaig—The island here is partly natural, though evidently adapted for habitation The west end is solid rock, but the south side seems to show signs of being artificially enlarged and there is a well-preserved causeway going zigzag to the shore The most interesting feature of this island is the large masses of vitrified material, one piece still in its original position being 8 feet long by 2 feet 6 inches high

Loch Pityoulish—Besides Mr Angus Grant, who first suggested this example, Rev Mr Macrae, The Manse, Edderton, writes: 'The island in Loch Pityoulish I often visited as a boy, and I remember it was always spoken of as artificial' I accepted the invitation of Sir John Macpherson Grant, Bart, of Ballindalloch, to motor to the loch and inspect it with him Captain Dunbar, the tenant of Pityoulish House, kindly placed his boat at our disposal, and we found the 'island'

covered by 18 inches of water The stones were of very even size and the slope of the island about one in five, the depth of water at the island's edge being about 8 feet On the N E side we came upon wood and made every effort to secure a log by means of the anchor and bring it to the surface But in this we were not successful From inquiries on the spot we learned that a causeway led from the island to a point on the N E bay of the loch, and that black oak had been found and had been taken away as a curiosity

Loch Knockie —I visited the islands in this loch in June The smaller island is certainly artificial and measures 30 feet by 12 feet, but the purpose of its construction 50 yards from the larger one, which measures 42 feet by 219, is difficult to explain I trust on a future occasion to examine the larger island more carefully

Loch Asalaich, Glenurquhart, and *Loch Farraline*, Boleskine — These islands, which were suggested as artificial, have not yet been examined, the latter presents some difficulty as it is now part of the reservoir for the British Aluminium Works at Foyers

The county of Inverness includes some of the Hebrides, but the examples which these afford will be best considered later

Ross and Cromarty

Loch Kinellan —This affords an interesting example of proof as to the island being artificial even by an unwilling witness Mr Herbert Corbett, the tenant of Kinellan, was at first most sceptical as to there being anything about the island that was not purely natural After some correspondence, however, Mr Corbett consented to seek for wood amongst the foundations of the island, and on October 15 he wrote · 'My brother and I first tried where I thought you had found the timbers and here we found a paved causeway, just beneath the water, extending some yards from the island We also thought we touched timbers at about 7 feet below the water-level and 10 to 12 feet from the shore—all this on the S E angle, so to speak, of the island Our sounding-pole clung so hard to the mud that we could not work properly, so we tried along the S side nearer the stones Here we found with an iron rod four beams about 6 feet apart in rather less than 4 feet of water. We then moved to the S W angle, where we found four more, much more irregularly placed as regards the radii of the island and much nearer together, not more than 3 feet apart There are also the stumps of the oak posts above water-level, that look as though they might have formed a pier at one time ' Mr Corbett also stated that the Ordnance Map showed the island to measure 558 of an acre A fortnight later he wrote 'Taking advantage of the fact that the snow prevented work in the garden, I took the men over to the island this morning and dug a hole 6 feet or so in diameter, and from 4 to 5 feet deep All the soil was made and had been piled in and was full of big and little boulders none larger than could be carried by one man I selected a spot near the middle of the S side where a kind of gap occurs in the stone wall of the island, and about 20 feet from the water-line At about 3 feet or less we came to a layer of sand, consisting mainly of white sand and broken pottery or what looks like it, forming a sort

of beach to a smaller island inside the present wall. Piercing the sand layer vertically and also at an angle of about 30 degrees, we found sharp and long-pointed stakes driven in groups, evidently with the intention of "containing" an earlier island than that now existing, and this probably was the basis of the present island. We found bones, sticks, and pottery of sorts (much broken) at all levels below 18 inches from the surface. I have left the hole open, so that if you can come over soon you can see the pit for yourself. I have lifted and preserved the stakes, and have kept out a sample of the "pottery sand" into which they were driven.'

As the Society of Antiquaries of Scotland had placed 5*l*. at my disposal to investigate any one island, and as other engagements prevented me from utilising this sum myself, I suggested to Mr. Corbett that he should undertake the work in regard to the Loch Kinellan Island. He very kindly replied: 'With regard to your suggestion about the Society's grant, I could not take it. I am not capable of doing such work, and have not the time for it. What I have done I have been glad to do for the interest of it, but I feel that I ought not to attempt more, as I may be spoiling the work for a more competent observer.' Here the investigation ended for the year, and I can only hope that Mr. Corbett's report may arouse sufficient enthusiasm for the island to be completely investigated. In consequence of the loch being used as the water-supply for the Spa Hotel, Strathpeffer, its level has been lowered at least three feet, so that this island offers very favourable, though not perhaps ideal, conditions, since a good deal of soil has been conveyed to the island in recent times to form a garden.

Loch Ailsh.—Mr. D. Macdonald, for many years Commissioner to Sir Charles Ross, of Balnagown, writes: 'I may mention that I was always of opinion that a small island in Loch Ailsh, which is on the course of the River Oykel, the boundary between Ross and Sutherland, is artificial; it seems to me to be constructed of rough unhewn stones regularly piled.'

Loch Tollie.—Mr. Donald Mackenzie, Inland Revenue, Bonar Bridge, writes: 'There is an islet in Loch Tollie, situated on the road between Gairloch and Poolewe. This islet, which is said to be a crannog, was occupied by McLeod of Gairloch towards the close of the fifteenth century.' Bartholomew's map marks this as crannog and not the following one.

Loch Kernsary.—Of this loch, three miles E. of the former, the same correspondent writes: 'There is a nice island called "The Crannog" in Loch Kernsary, about $1\frac{1}{2}$ mile to the eastward of Poolewe. When last I saw it there was a rookery on it. I know nothing of its history.' He further states: 'There is an islet said to be a crannog in *Loch Mhic Ille Riabhaich* $4\frac{1}{2}$ miles E. of Poolewe.'

Loch Achnahinneach in Kintail is the same loch as that mentioned by Mr. Mackenzie as Loch Ach-an-darrach. It has been carefully investigated by Mr. George Forbes, Fernaig, Strome Ferry, and affords one of many instances of incorrect information supplied as to the recent date of an island, later found to be of much earlier date. The following

are extracts from Mr Forbes' letters 'I have been trying to see some of the oldest inhabitants of the estate, as I was told that the island was built in Sir Alexander Matheson's time, but the correct history I only obtained to-day when I visited the loch. The island is on Loch Achnahinneach about four miles from here in the parish of Loch Ailsh, County of Ross It is quite small and was disappearing altogether when they raised the level of the loch, and it was then that Sir Alexander did some repairs to it It has been inhabited at one time and the house has been built on oak piles, all that meets the eye now is nothing more than a pile of stones where about 30 or 40 seagulls have their nests every year The island is round and not more than 30 feet in diameter, but I expect it had been much larger before the level of the loch was raised' In a later letter Mr Forbes writes 'I have two other lochs here which I intend to visit whenever I can find time, they are a considerable distance away, but I hope to be able to inspect the islands on them during the month of June I am sure there are plenty of others, and I will try and find out about them from keepers and then visit them with the camera'

In close proximity to Loch Kinellan, mentioned above, occur *Loch Ussie* and *Loch Achilty*, as to both of which reports have been sent in by Mr Hugh Fraser, M A, Dingwall The islands in the former appear to be natural, but a causeway exists between the shore and the larger of the islands, the causeway is said to go zigzag The Loch Achilty island was found to show wood projecting from the rubble on the S W and also on the N W, while at the East end the island has been damaged by water-wear and the timbers are to be seen in numbers The island measures 60 feet by 42 feet and is distant fully 80 yards from the shore, the water is deep all round, nowhere apparently less than 15 feet Regarding these three islands it is worthy of note that the district is rich in other prehistoric remains Mr Hugh Fraser also sent me details of the island on *Loch Glass*, which he says appears from the shore to be a heap or cairn of stones in fairly deep water In this case also he mentions the existence in the neighbourhood of cup-and-ring marked stones and ruins of circular dwellings His description and photograph of the island in *Loch Morie* prove it to be of very similar construction Mr J Meiklejohn, factor for Mr Munro Ferguson, of Novar, writes in similar terms, and gives the size of the Loch Morie island as ten yards by seven

Loch Beannachan —Mr Hugh Fraser undertook to visit this island from Dingwall, but his experience was a not unusual one 'I spent a day,' he writes, 'in going to Loch Beannachan only to find the island entirely under water, and what was worse to be misdirected as to its location' Of this island Mr John MacLennan writes 'I do not know of a crannog on Loch Luichart, but I have strong reasons for believing there is one in Loch Beannachan, and I have filled in the form with reference to it This island is only visible at low water, and is 200 yards from the shore at the E end of the loch About half a mile E of the crannog there appear to be the remains of an old Druid circle The farmer's son at Carnoch dug inside the circle seven or eight years ago and found a brass ring, now in his possession. About forty years

ago a stone cist was unearthed in a small mound by the brother of said farmer.'

Loch Achall, Ullapool.—Mr. Hay Mackenzie, National Bank of Scotland, reports: 'There is a small island or cairn of stones in Loch a Coll, Rhidarrock Forest, two miles from Ullapool, which is said to be artificial . . . There is a path now covered with water leading to it, but which can easily be seen when the water is clear.'

Loch Dhughaill, Achnashellach.—Mr. Norman Reid, one of the judges of the Scottish Land Court, spoke at some length about the island in this loch. In filling up the schedule he added: 'The island is only above water when the loch is very low. It is about 100 yards from the shore. Some years ago oak sticks were washed ashore from it; they had been fastened together with large wooden pins.'

Loch Gobhlach.—In this loch, which is just across the boundary between Ross-shire and Inverness-shire, Rev. D. Mackay, Marydale, Strathglass, is confident that there are two entirely artificial islands, one of them with an evident causeway to the shore.

Sutherlandshire.

Loch Craggie.—The island in this loch, which is at the E. end of Loch Craggie, has every appearance of being artificial. It measures 46 feet by 34 feet, and is 3 feet 6 inches above the average level of the loch. It is situated 110 yards from the shore, and is composed of stones of all sizes, without the appearance of any woodwork, nor can any causeway to the shore be traced. On the other hand, the floor of the loch is quite clear of stones beyond the limit of the island, so that there is little doubt but that it is artificial.

Of *Loch Clibrig* Rev. Mr. Macrae, Edderton, writes: 'Here there is an island with a distinct causeway to the shore.' In *Loch Shin* Mr. Curle suggests four islands as possibly artificial.

The island of *Loch Migdale* is similarly reported by Rev. Mr. Macrae, whilst Mr. Donald Mackenzie, Inland Revenue, Lairg, sends me the following quotation regarding this set of islands from the 'History of the Earldom of Sutherland,' by Sir Robert Gordon, who wrote in 1630: 'In sundrie of these laikes ther ar ilands with habitations, as in Lochshin, Lochbroray, Loch-Migdale, Loch Buy, Loch Dolay and others. There are four islands in Lochshin . . . all pleasant dwellings in summer.'

Mr. Donald Mackenzie also suggests the island in *Loch Loro*, on the confines of the parishes of Cruich and Lairg, which a gentleman who had seen it recently considered to be artificial.

In the Lochinver district Rev. Angus MacIntyre thinks he can identify several islands as artificial. Mr. MacIntyre had collaborated with Dr. Erskine Beveridge in the latter's excellent topographical works on Coll and Tiree and on North Uist, and he has thus exceptional opportunities of observing the construction of these islands. He writes: 'I have not yet been able to verify several islands that have come under my notice, but feel quite or almost quite sure that they are the genuine article; one is at the W. end of *Loch Assynt*, one in *Loch Awe* at Inchnadamph, one in the loch (Borrolan) immediately

in front of Aultnacealgach Hotel, and two in *Loch Cama* at Elphin—five in all I propose on or after July 12 to make an exhaustive examination of all these, and report directly thereafter.'

Loch Tigh Choimhead.—In reference to this loch Dr Hew Morrison, LL D , writes 'In my native parish of Tongue, Sutherlandshire, there is a loch about two miles from Torrisdale, called Loch Tigh Choimhead, that is the Loch of the Watch House In that loch there is a green island, which has become more and more submerged in my own memory. My brother, who is a strong swimmer, went to the island at my suggestion some years ago, and with a long stick sounded the various parts of it, and thought that it was very likely founded on piles or some kind of wood It might also be worth while examining many of the lochs in the northern part of the county Not far from this loch which I have referred to there are brochs, and in the near neighbourhood are two large boulders with cup marks on them '

Loch na Hacon, Tongue.—Mr Evander Mackay, Farr Schoolhouse, Thurso, suggested that the island on this loch was artificial He had visited it many years ago, and had noticed a causeway leading to it from the shore

Caithness

On application being made to Mr Robert McClements, Schoolhouse, Keiss, this gentleman communicated with Mr John Nicolson, Nybster, who is greatly interested in antiquarian matters and is thoroughly acquainted with all parts of the county Mr McClements reported : 'In *Loch Alterwall* there is an artificial island The loch was drained about fifty years ago by Sir John Sinclair, who led a burn from the loch and so left the island dry On the island is a small dry-built structure whose walls are 5 feet thick, with five steps leading down. A jug was found in parts, which Mr Nicolson pieced together, and of which he sends a sketch He has the jug in his house.

'At the E end of *Loch Watten* there is a small island, a round heap of stones about 4 feet above water and 200 yards from the shore. The *Loch of Stemster* has a small island planted with trees An island in *Loch Rangag* has a broch built on it *Loch Calder* has a natural island which has a hut circle built on it '

Sir John Sinclair reports as follows 'Loch Alterwall.—This island was investigated by Sir Francis Barry in 1900, when a square building and staircase were found Lake Dwelling on Stemster.—This is an island in the Loch of Scarmlett in the Stemster district of Bower Parish, and not in the Loch Stemster in the parish of Latheron. It has now trees growing upon it, but before the trees were planted there were indications both of a building and of a staircase . . . The dwelling in the island in the Loch of Rangag is an ordinary small broch of about 20 feet diameter, and it is always quite easy to wade out from the shore to the island '

Mr. John Davidson, West Watten, suggests an island in *Loch Toftingall* as possibly artificial In the near neighbourhood of this loch are Standing Stones and at least four Picts Houses.

Orkney and Shetland.

Mr James Murray, of the Lake Survey, suggested the island on *Loch Skaill* as being artificial

Mr James Johnston, Orphir House, Orkney, further suggests among the numerous islands on the lochs of Orkney one on *Loch Wasdale*, with site of chapel; *Loch Clumly*, the island of which has a broch on it, *Loch Sabiston*, where there are stepping-stones leading to the island, *Loch Isbister*, the island of which has a broch on it

Shetland —Mr J D Mackintosh, Lerwick, replied to the circular 'I understand that there are some such (artificial islands) in Shetland, and I think if you sent me half a dozen of the circulars I could get some information from various parts of the islands of Shetland . ' At the time of writing these forms had not been returned Dr Th Johnston reports that the *Loch of Cliff*, in Unst, has an island cairn, but no causeway observed

Argyllshire and the Western Islands

On the main land of Argyllshire there have been suggested three islands in Loch Nell, the one called Loch a Mhuillinn at Oban, one or perhaps two in Loch Awe, and one in Loch Ternate, Morvern Those in *Loch Nell*, briefly mentioned by Dr Munro, were visited and photographed by Dr W D Anderson, Oban Dr Anderson reported that there were two artificial islands still above water, and two others submerged, and mentioned that his photo 'showed the serpent mound on the mainland behind the island and a little to the left of the picture ' This item is recorded in view of the question which was added to the original circular by one of the members of the Committee as to whether there are any artificial mounds or other structures in the alluvium on the shores of the loch The 'Serpent mound' was visited and examined by Dr Phene, who found at one end a prehistoric burial, the contents of which were sent to the museum at Edinburgh I must, however, add that Dr Joseph Anderson considers the mound a natural one, and that Dr Phene was mistaken Subsequently Dr Munro visited the locality and saw the remains of a cist in the terminal end of a wavy morainic ridge Mr R D Murray Allan, of Glenfeochan, kindly sent a tracing of the loch showing the position of the two visible islands, and also that of the submerged ones

The island in *Loch a Mhuillinn* was suggested by Mr D McIsaac, who exhibited a photo of the crannog being dug, and, in addition to the workmen, the photograph showed Professor Heddle, of St Andrews, and several members of the Town Council of that day Mr McIsaac also showed a piece of one of the logs The crannog, which was first discovered by Mr Campbell, then Burgh Surveyor, was about 85 feet long by 53 feet broad Dr J A Harvie-Brown, on whose yacht Professor Heddle was staying, sent me a copy of the photo along with the following extract from his note-book · '15th May 1888 We inspected, along with Provost Drummond and Mr. Munro, Oban, a new discovered lake-dwelling built on piles in the middle of Loch a Mhuillinn, which lies close to the town and railway embankment, and

which lately a loch, is now a deep stinking bog of mud and decayed vegetation . . . The whole crannog is some 84 feet long by 56 feet wide—one of the largest discovered '

Loch Awe —Mr Donald Macdonald, Taynuilt Hotel, writes: 'I have come across an old man of seventy-nine, John McGregor, who knows Loch Awe from end to end He tells of an artificial island on the loch opposite Ardnassaig House In the old days Ardnassaig was called New Inverawe When McGregor was ten years old he remembers quite well seeing men building this small island, which is about 12 yards long Old Mr Campbell, of New Inverawe, noticed one day, when the loch was very low, some stones appearing under the surface of the water He then got a lot of men to gather stones and earth to make up this mound When finished he had some trees planted ' It would thus appear that Mr Campbell, perceiving that the island was being submerged, heightened it on this occasion All experience goes to show that these islands were constantly sinking under their own weight, and that even at the time when they were being inhabited layer after layer of material was added, so that frequently three and four hearths are found one above the other.

Mr Francis Darwin suggested the island opposite Inverliever In reply to the circular Mr H E Bury, present tenant of Inverliever, wrote: 'West of the Inverliever burn there is a wooded promontory, which in very high floods is an island Round this promontory is a bay, and in the next bay west of this is the island in question It is composed of a mass of stones, in the otherwise sandy bay, and is about 50 yards from the shore At the ordinary level of the loch the top of it is about 3 feet out of the water, and I should certainly say (and so does my friend, Mr J B Hill, who was Geological Surveyor for many years for that part of Scotland) that the island is artificial I think there are signs of a causeway to the shore '

Loch Ternate —This island was suggested as artificial by Mr. A Nicholson, of Arisaig, and Mr John Ross, keeper, sent some interesting traditions about it, but without determining the question as to whether or not it was so

Loch Kielzievar and Torlundi —The examples here are mentioned in the Transactions of the Society of Antiquaries of Scotland, 1867 and 1868, but do not appear in Dr Munro's volume ' Ancient Scottish Lake Dwellings,' which I had taken as the standard authority After the two lists of suggested islands had been printed and the present report almost completed I found that they are included in the author's ' Lake Dwellings of Europe,' published a few years after the first-mentioned volume This same remark applies to some of the other islands in this paper

Isle of Mull —My letter to Messrs Lindsay, Howe, and Co was forwarded to the Duke of Argyll, who kindly answered it himself 'Mar 12, 1912 I received last night a typed letter with your signature asking about artificial islands That on *Loch Baa*, Salen, is opposite Mr. Melles' house, on my side of the loch, and is a cairn of stones. There are one or two, under water, off this low shore, at foot of Glen Clachaig, in the same loch, but these may be mere mounds

of stone at the foot of some old glacier The island opposite Mr Melles house must be at all events largely artificial It is small '

Tiree —Miss Elspeth Campbell writes from Inverary Castle: 'I would suggest two islands in *Loch Bhasapol*, in Tiree They are without doubt artificial and should be of interest; both islands are fairly close to the shore, but there is no trace of a causeway In fact, the bottom of the loch is sand and mud, though the islands are built of large stones No one knows their origin. The two islands are at different ends of the loch, half to quarter mile apart One is very small, the other slightly bigger—almost big enough for a small fort ' Regarding these islands, Mr Peter Anderson, gamekeeper, Scarinish, sends the following details ' As regards the islands on Loch Bhasapol, I have been on them hundreds of times while duck-shooting *Eilean Mhic Conuill* is entirely artificial, and there are a few stones, the remains of a causeway, towards the N W There is an entire absence of stones both on the floor of the loch (which is sand) outside the limits of the island The island is about 18 yards across, partly under water

'*Eilean Aird na Brathan* appears to me to have been a much more important place It is partly artificial, the stones are very much larger, and they must have had great difficulty in getting them there. It is 50 yards from the shore, and the water round is 3 to 4 feet deep The island is 15 yards by 10 yards The other islet that is partly artificial is in *Loch na Gile*, and is just as Mr Beveridge mentions in his book ("Coll and Tiree," page 115) ' Mr Anderson also considers the island in *Loch na Buaile* as probably artificial

Coll —Besides Tiree, the islands of Coll and N Uist have been described by Dr Erskine Beveridge, LL D , whose careful investigation and excellent illustrations make one wish that other districts in these distant parts could find so able an historian It is unnecessary here to give more than a brief summary of his account of the island Duns He states that they are somewhat numerous in Coll, and that all have evidently possessed "clachans" or causeways for approach The island in *Loch Fada* is 20 yards from the shore, with a causeway from the N Half a mile S of this is *Loch Ghille Caluim*, the island in which can be reached in a dry summer by wading It measures about 20 feet in diameter The islands on *Loch Rathilt*, *Loch Urbhaig*, and *Loch an Duin* all have causeways to the shore All the above Dr Beveridge considered as probably artificial In *Loch Chad* there are two natural islands, each of them approached by a causeway About 15 yards S W of these ' is a smaller islet of stones, to all appearance entirely artificial,' and connected with one of the larger islands by a causeway The Upper and Lower Mill Lochs—marked on the Ordnance Map as *Loch nan Cinneachan* and *Loch Anlaimh*—both contain islands, evidently artificial, ' with well-preserved causeways, through rather deep water '

Isle of Eigg —Just N of the foregoing islands is the small isle of Eigg, measuring 3 by 4 miles In it is the little *Loch na Mna Moire*, with a distinctly artificial island Rev F. McClymont writes · 'I thought it might interest you to know that there is one of these islands in a loch here It goes by the name of the Loch of the Big Woman. There is a funny tradition of its being inhabited by abnormally big

women, who use stepping-stones so far apart that none else could use them.' The island is 50 yards from the shore, and measures 35 by 15 feet.

Isle of Skye—Although artificial islands are so common in the other Hebrides, the only one reported from Skye as probable is that mentioned by Major Kenneth Macdonald, of Skeabost, 'in the old Loch of Monkstadt, now drained There are the remains of an old monastic building, on what was an island in the loch The loch was drained about eighty years ago, and now gives a wonderful crop of hay' Hon Godfrey Macdonald, Armadale Castle, and MacLeod of MacLeod both write that they know of no artificial islands on their properties, which comprise by far the greater part of Skye

In singular contrast to the preceding, artificial islands occur in a continuous line throughout the Long Island In *Barra* there is one in Loch an Duin, close to the road from Castlebay to North Bay In S Uist they occur almost exactly every three miles, and may be seen from the high road which runs through the centre of the island That on *Loch Dunnakillie* has the remains of buildings upon it, and is a fairly large island In *Loch na Faoillen*— a small loch only a quarter of a mile across—there is an excellent specimen, with causeway to the shore When staying in S Uist in 1909 I had this island for six weeks just opposite my house, though it was with some difficulty that I had a tiny boat put on the loch and landed on the island It is 50 feet in diameter, and is certainly artificial. The causeway to the shore, though quite distinct, is now unpassable except as a trial of skill Three miles further N, and again alongside the high road, there is another similar island, with causeway, in *Loch a Mhuillinn* To these, which I frequently saw myself, Rev Alex Macdoughall adds the islands in *Loch Ard Bornish*, *Loch Ceann a Bhaigh*, in the Ormaclate district, *Loch Alt a Briac*, in the Stoneybridge district, and in *Loch Druidibeg*, in the Stillingarry district These are quite independent of the great number of natural islets with which most of the lochs abound, and which make the presence of so many of the artificial islands all the more surprising

Benbecula—Regarding the examples in Benbecula, I have the promise of a full report from Dr Eric Gardner, M D

North Uist—As already mentioned, N Uist has been fully and most ably described by Dr Erskine Beveridge in his work published as recently as last year Treating of island forts, he says 'Our list includes no fewer than seventy island forts, each as a rule provided with a causeway from the neighbouring shore, whilst in exceptional cases it would seem that the only access was by means of a boat The causeways show considerable divergence in type, and most of them have evidently been submerged to the extent of 12 or 18 inches, though others stand at about the normal surface of the loch It was of special interest to find seven of these approaches interrupted by structural gaps, obviously arranged so as to give additional security Again, and no doubt with a similar purpose, the causeways display much irregularity of outline, in general taking a curvilinear form, but sometimes that of zigzag, or of a double curve, shaped like the letter S' (page xv)

Treating of Prehistoric Forts, in Chapter VI, the author adds a footnote 'To all appearance several of the minor island forts have been built upon foundations at least partly artificial, though it seems obvious that in each case the site was chosen so as to take advantage of natural conditions already existing'

In a letter of August last Dr Beveridge wrote 'I am now able to send you particulars of the apparently artificial islands in N Uist I have classed seven as such, numbering them 1 to 7, and five others are doubtful, whilst there may be a few others which are less obvious as to character Of the twelve I have only photographed six, and send copies herewith' No 1 is the island in *Loch an Duin*, Portnain, known as Dun Nighean righ Lochlain It is about 30 feet in diameter and 30 yards distant from the shore, with well-marked causeway Stone circles and a chambered cairn exist in the near neighbourhood No 2, *Loch an Duin*, Breinish, also known as Dun Nighean righ Lochlain This measures 28 by 32 feet, is distant 25 yards from the shore, and has a distinct causeway The two islets in *Loch Obisary* Mr Beveridge considers doubtful The one measures 18 feet in diameter, the other 60 feet, but neither has any causeway visible The two islets in *Loch Mor*, Balesbare, are classed as certainly artificial One measures 40 feet in diameter, the other less In each case there is a causeway about 5 feet wide The two islets in *Loch nan Gearrachan* are also certainly artificial One measures 32 feet across, the other 29 feet by 41 feet They are distant respectively 35 and 25 yards from the shore, and each has its causeway The island in *Loch Eashader* is of the 'certain' class It measures 52 feet across, is distant 40 yards from the shore, but the causeway in this case is doubtful The *Loch Aonghuis* island is 'doubtful,' as is also that in *Loch Oban Trumisgarry*, but this latter has a causeway to the shore, a distance of 30 yards.

Harris —Mr J Wedderspoon, C E, a prominent member of the Inverness Field Club, sends particulars of two islands in Harris 'The first find was in the island of *Scalpay* near Tarbert I had occasion to visit the island in connection with a water-supply to the school proposed to be taken from a small loch near the centre of the island, bearing the common name of Loch an Duin' Mr Wedderspoon mentioned that there are two islands about 20 yards apart, and that both have the appearance of being artificial, although one is more strikingly so There is a causeway from the shore, and this appears to be continued between the two islands

The other example is on the *Island of Taransay*, off the W coast of Harris, which also contains a Loch an Duin There is a causeway from the shore a distance of about 40 yards and the island measures 35 feet across Mr Wedderspoon made exact measurements of the building on the island, which however he considers of much later date than the island itself

Lewis —Mr James Fraser suggests the island on *Loch an Duin*, near Loch Carloway, and that on a *loch near Bragar*, seven miles further north on the W coast of Lewis Mr. C G. Mackenzie, Procurator Fiscal, Stornoway, suggests the islands on *Loch Arnish* and *Loch Chlathamir*. 'In the first of these the foundations of the

islet seem to be formed of rubble work, and the same remark applies to the twin islands on Loch Chlathamir On several little lochs of the island the common brochs or duns are to be seen '

Mr K J Ross, Bank of Scotland, Stornoway, writes 'Quite recently another instance of an artificial island, which does not appear on the list, has been brought to my notice It is situated on *Loch Orisay*, which appears on the reduced survey map as Loch Eilean Mor, about seven miles from Stornoway, in a westerly direction I do not think there can be any doubt about its being artificial, for the person who brought it to my notice had never seen or heard that artificial islands of the kind existed, yet he was quite positive that it had been built by the hand of man '

One of the most interesting examples of the whole series is that at *Tolsta*, first suggested by Rev W Morrison, M A , F S A Scot , who writes 'At Tolsta, some twelve miles north of Stornoway, on the croft of a Mr McIver, a small shopkeeper, I saw a lake bottom on this croft He had drained the loch with a view to adding it to his croft He was astonished that with the exception of a small mound on the otherwise arid area he could get no crops to grow I suggested that the mound was a lake-dwelling He at once agreed that it must be so, for he found stakes stuck all round the mound He added that he found fragments of clay pottery, which he threw aside as of no value to him This took place several years ago If Mr McIver is in life he will assist you with good-will Lake-dwellings should be found all over the interior of the island of Lewis '

The following delightful letter from Mr C G Mackenzie, Procurator Fiscal, Park House, Stornoway, gives further details [the letter is given in full as a sample of the many pleasant letters which this inquiry has brought me] 'July 30, 1912 I have had an opportunity of visiting the site of the lake at N Tolsta, as to which you wrote me some time ago I saw Mr McIver and got some details from him The superficial area of the loch was something about 1½ acre It appears that the existence of the island was unknown until as the water of the loch was being drawn off the islet revealed itself It proved to be almost 12 yards square and appears to have had a foundation of heather with "built stones about it " On the island were found a quantity of mussel-shells, deer-horns, and *snuff-mills* made of stone There was a causeway leading to the islet, and stakes were discovered sticking out of the ground along the track of the causeway The stones, etc , forming the islet were removed, and while utilising the site for agricultural purposes, a curious discovery was made Under the heather were found immense quantities of diatomite Mr MacIver tells me that at one part of the loch he forced a 15-foot iron rod into the diatomite and found no bottom

'While in North Tolsta I saw a loch in the near vicinity of the one under notice on which an islet is situated From the general appearance of the island I do not doubt that it is a built one At *Aird* in the Eye Peninsula I examined an island in Loch an Duin A causeway of stone leads from the shore to the island, and this island, too, I regard as artificially formed Whether the stones forming

the island are the remains of a Dun, or are the actual foundations, is not now easily determined, but I incline to the view just stated.

'In addition to those mentioned in my former letter, there appears to be an artificial island on *Loch Orisay* (spelt phonetically) between Grimsheder and Loch Chlathamir, in the parish of Lochs The Road Surveyor, Mr MacLeod, informs me that the island is undoubtedly a "built island" It may be of interest to know that some years ago, when alterations in the water-supply system to Stornoway were rendered necessary, the loch from which the town's water is drawn (*Loch Aird-na-lice*) had to be partially drained At the N W. corner of the loch, some yards from the shore, a perfectly formed island was exposed consequent on the draining operations, and it still exists, but now, of course, totally covered by water If I remember rightly some stakes were found about it I am afraid I have not helped you much, but if I can be of any further service, please command me—Yours very truly, C G MACKENZIE'

With the example at Tolsta, the most north-westerly point of the British Isles, and a site which may yet prove of the greatest interest, I shall conclude this list of the Artificial Islands which have been notified in reply to the circular issued by the Committee That so large a number have been suggested is surely matter for congratulation, for even if some should eventually be found to 'draw blank,' the evidence in the vast majority of cases is quite conclusive

Remembering, as I do, the welcome accorded to my paper suggesting the first addition to the then-known examples, I cannot but wish that the same congratulations should be offered to each of those who have succeeded in adding to the list I feel sure that I am expressing the feelings of the Committee when I cordially thank each of the correspondents for the information which they have, often with considerable trouble, elicited in regard to the examples in their various districts

Table showing the Geographical Distribution of all the Islands, suggested as Artificial or proved to be such, within the Highland District of Scotland and the Islands

Islands mentioned in Dr Munro's Ancient Scottish Lake Dwellings	Islands newly suggested or about which fresh information is given in the foregoing Report
1 *Aberdeenshire*	
Loch Canmore, Banchory, Federatt, Peel Bog	Loch Kinnord
2. *Argyllshire*	
Kielziebar, Loch na Mial (Isle of Mull), Ledaig, Lochnell, Parish of Kilchoman (Islay), Fasnacloich	Loch Awe (island near Ardnasaig) (island near Inverliever), Loch Ternate, Lochnell (four islands), Loch a Mhuilinn (Oban), Loch Baa (Isle of Mull), Loch Assopol (Isle of Mull), Loch Poit na h-I, Loch Bhasapol (Tiree, two islands), Loch na Gile (Tiree, two islands), Loch na Buaile (Tiree, two islands), Loch Fada (Coll), Loch Ghille Caluim (Coll), Loch Rathilt (Coll), Loch Urbhaig (Coll), Loch an Duin (Coll), Loch Cliad (Coll), Loch nan Cinneachan (Coll), Loch Anlaimh (Coll)

Islands mentioned in Dr Munro's Ancient Scottish Lake Dwellings	Islands newly suggested or about which fresh information is given in the foregoing Report
3. *Buteshire*: Loch Quien, Dhu Loch.	
4. *Inverness-shire*: Loch Lochy, Loch in Croy (drained), Loch Gynag, Loch Moy	Loch Ness, Loch Bruiach, Beauly Firth, Loch Moy, Loch Garry, Loch Oich, Loch Lundi, Loch Treig, Loch nan Eala, Loch Meiklie, Loch Lundavra, Loch Ruthven, Loch Arkaig, Loch Pityoulish, Loch Knockie, Loch Assalaich, Loch Farraline, Loch na Mna Moire (Isle of Eigg), Loch Monkstadt (Isle of Skye), Loch an Duin (Barra), Loch Dunnakillie (South Uist), Loch na Faoillen (South Uist), Loch a Mhuillinn (South Uist), Loch Ard Bornish (South Uist), Loch Ceann a' Bhaigh (South Uist), Loch Druidibeg (South Uist), Loch an Duin, Portmain (North Uist), Loch an Duin, Breinish (North Uist), Loch Obisary (North Uist), Loch Mor, Balesbare (North Uist), Loch nan Gearrachan (North Uist), Loch Eashader (North Uist), Loch Aonghuis (North Uist), Loch Oban Trumisgarry (North Uist), Loch an Duin (Isle of Scalpay, Harris), Loch an Duin (Isle of Taransay, Harris)
5. *Perthshire*: Loch Rannoch, Loch Clunie, Loch Earn, Loch Ard, Loch Laggan, Loch Morall, Loch Tummel, Loch Tay, Loch Freuchie, Lake in Blairgowrie, Loch Moulin (drained) Loch Granech, Loch Tulla (this loch is in Argyll), Loch Monivaird, Loch Achray, Loch Vennachar, Loch Kinnard	Loch Rannoch, Loch Earn, Loch Hoil, Loch Derculich, Loch Essan, Loch Tummel, Loch Tay, Loch Ochtertyre, Loch Moulin
6. *Ross and Cromarty*: Loch Kinellan, Loch Achilty, Loch Glass.	Loch Kinellan, Loch Achilty, Loch Glass, Loch Ailsh, Loch Tollie, Loch Kernsary, Loch Mhic Ille Riabhaich, Loch Achnahinneach, Loch Ussie, Loch Morie, Loch Beannachan, Loch Achall, Loch Dhughaill, Loch Gobhlach Also in the Isle of Lewis, Loch an Duin, Loch Bragar, Loch Arnish, Loch Chlathamir, Loch Orisay, Loch Tolsta, Loch Aird-na-lice
7. *Stirlingshire*: Loch Lomond.	Loch Lomond
8. *Sutherlandshire*: Loch Brora, Loch Shin, Loch Do'ay	Loch Craggie, Loch Shin (four islands) Loch Clibrig, Loch Migdale, Loch Loro, Loch Assynt, Loch Awe, Loch Borrolan, Loch Cama (two islands), Loch Tigh Chaimhead (Tongue), Loch na Hacon (Tongue).

Islands mentioned in Dr Munro's Ancient Scottish Lake Dwellings	Islands newly suggested or about which fresh information is given in the foregoing Report
9. *Caithness*	Loch Alterwall, Loch Watten, Loch of Stemster, Loch Rangag, Loch Calder, Loch Toftingall
10. *Orkney and Shetland* .	Loch Skaill, Loch Wasdale, Loch Clumly, Loch Sabiston, Loch Isbister, Loch of Cliff (in Unst)

Archæological and Ethnological Researches in Crete.—Report of the Committee, consisting of Mr D G HOGARTH (*Chairman*), Professor J L MYRES (*Secretary*), Professor R. C BOSANQUET, Dr. W. L H. DUCKWORTH, Sir A J. EVANS, Professor W RIDGEWAY, *and* Dr. F. C SHRUBSALL.

CONTENTS

Report to the Committee By Dr W L H DUCKWORTH

Particular attention is directed to

(*a*) The 'Armenoid' type of cranium in the interments of Minoan antiquity in Crete (*cf.* Part II)

(*b*) The presence of pygmy individuals in Crete during the Neolithic period (*cf.* Part III).

(*c*) The distribution of the cephalic index in Greece (*cf* Part IV. and Map No. I).

THIS Report constitutes an extension of the Special Reports (*a*), (*b*), and (*d*) published in Part II of my Report in 1903.[1] It will be convenient to submit first the observations bearing upon my Special Report (*b*), which dealt with the modern inhabitants of Sitia

PART I.—*The Modern Inhabitants of Crete, especially those of the Province of Sitia*

In this connection I am glad to have an opportunity of referring to Mr C. H Hawes' remarks, published in 1910,[2] as Appendix III to a Report furnished in that year to the Cretan Committee. And I must thank the Secretary of the Committee (Professor J L Myres) for having given me an opportunity of studying Mr Hawes' remarks before the final publication of the Report. I have now gone into the

[1] *Cf. Brit. Assoc. Reports*, Southport, 1903, pp. 406, *et seq.*
[2] *Cf. Brit. Assoc. Reports*, Sheffield, 1910, p. 251.

matter as fully as I can, and have come to the conclusion that Mr. Hawes has made out a most convincing case in favour of the recognition of an 'armenoid' element in the modern population of Sitia

Reference to Mr Hawes' remarks in 1910 will show that he urged this view of the Sitians against my suggestion that they were colonists of 'illyrian' affinities introduced by the Venetians So far as the matter is controversial, I readily accept Mr Hawes' correction With characteristic modesty, Mr Hawes[3] describes his view as a 'hint', and he sets this hint against what he calls my suggestion The latter description is correct, but Mr Hawes can, in my opinion, claim far more for his view, for it seems as near a demonstration as we are likely to obtain in such matters

In 1903 I was not altogether unmindful of the possibility of finding the 'armenoid' type in Crete It is perhaps worth mention that in my notes I described one of the Minoan crania from Palaikastro (No 2D) as of 'armenoid' aspect Of this I shall have more to write in the sequel But as regards the observations on the living, I was somewhat prejudiced (against the 'armenoid' view) by three considerations In the first place, I happened to meet with an Armenian in Candia, and was much impressed with the extreme nigrescence of hair and eyes, together with the thin aquiline nose In Sitia I failed to recognise these features, at any rate in combination, and in particular I find frequent references in my notes to the comparative fairness of the moustache among the Sitians Lastly, the individual most 'armenoid' in appearance among the Sitians measured by me provided a cephalic index of 74 1—almost the lowest figure in my list

These remarks are not to be taken as expressive of any reserve in my adoption of Mr Hawes' exposition, but rather as indicating that the 'armenoid' type is perhaps different from the Armenian, or that it is not found in its original and unaltered form in Sitia These are matters for future investigation, and as such they will not be discussed any further in this place

In following Mr Hawes' descriptions and inferences as expressed in his 'Remarks' and in his subsequent and admirable paper on the Dorians,[4] I was careful to test his conclusions on my own observations of Sitians The result is fully confirmatory of the statement that the Sitian head is characteristically short For purposes of comparison I selected thirty men from the province of Sitia (measured by me) One provided a cephalic index of 83 3, while all the rest gave indices of 84 or more The mean value of this index in the thirty examples is 86 3 These and other data are most concisely given in the form of a table, to which I add Mr Hawes' data for Sitians, as well as those published in the 'Remarks' (p 255), to exhibit the likeness between the Sitians of Crete and the Takhtadji of Asia Minor, as well as the contrast with the Selinots (compared by Mr Hawes with the Albanians):

The agreement is very close in the case of columns I, II, and III, while they are in marked contrast with the data (for the Selinots) in

[3] 'Remarks,' 1910, p. 252.

[4] *Annual of the British School at Athens*, No. XVI, 1909–10, pp. 258, *et seq.*

TABLE I

Measurements in Millimetres	Crete		Asia Minor	Crete
	Sitians	Sitians	Takhtadji	Selinots
	(30 most brachycephalic)* Duckworth	71 Hawes	13 Petersen (quoted by Hawes)	33 Hawes
	I	II	III	IV
Head Length	178 6	180 1	178 8	185 3
Head Breadth .	154 1	153 2	153 2	157 2
Cephalic Index	86 3	85·1	85 7	85 0
Stature	1682	1678	1679	1701

* Their names appear to be characteristically Greek, but Mr Hawes has pointed out the unreliability of this test of ethnic relationship

column IV I have but one criticism to make—viz, that regard must be paid to the greater bulk of the latter (the Selinots), in whom the head must therefore be somewhat larger This is seen to be the case, while the cephalic index is not very different from those in the remaining columns That the cephalic index should be reduced (as it is) is intelligible in consideration of a general law, formulated by Johannsen, as to the relation between this index and the stature

Apart from this, the conspicuous shortness of the Sitian, and, I may add, the 'armenoid' head, led me to consider this feature as a possible test for 'armenoid' heads as contrasted with those of 'illyrian' affinities And, as I have been working out some results of my observations on Greeks of the mainland, I may anticipate here part of the section of this Report dealing with the latter For the purpose of a comparison, I pitted the thirty most brachycephalic Sitians of Crete (cf Table I, column I) against the forty most brachycephalic of my Greeks The result is striking, but not satisfactory For the sake of brevity I have presented it in the form of the Table (II) which follows —

TABLE II

	Mean Cephalic Index	Mean Head Length	Mean Head Breadth
Sitians (30) .	. 86 3	178 6	154 1
Greeks (40)	87 5	178 9	156 1

	Head Length over 182	Head Length 182	Head Length less than 182
Sitians . .	6 20 %	4 13 4 %	20 66 6 %
Greeks .	13 . 32 5 %	5 12 5 %	22 55 0 %

	Head Breadth over 155	Head Breadth 155	Head Breadth less than 155
Sitians .	. 13 .43 3 %	3 .10 %	14 46 7 %
Greeks . . .	22 .55 0 %	6 ..15 %	12 30 0 %

The result is striking, because, if the figures be accepted as they stand, a strong suggestion is provided of an 'armenoid' as contrasted with an 'illyrian' element on the mainland Short heads are found in both the groups (Sitians and Greeks) compared

But we cannot take the data absolutely without correction, for the Greeks were immature. Although of a mean age of about nineteen

years, one or two were certainly younger than this It follows that the value of the head-length as provided by these Greeks is not precisely comparable with that of the Cretans of Sitia Some elongation of the heads of the Greeks would certainly have to be allowed for, although I do not believe it would amount to more than 5 mm in any case, and would probably be about 3 mm on the average (On the other hand, the stature, which is not given, does not cause any complication in this comparison) On the whole, therefore, there is some suggestion of an armenoid element even in the Peloponnese If this were substantiated, the result would be extremely interesting, for it is almost certain that the armenoid and illyrian types would be in contact much more closely in Greece than in Crete, where, as Mr Hawes has shown, they are separated by a zone occupied by a dolichocephalic element identified with the Mediterranean type [5] An investigation of the inhabitants of Eubœa might be very instructive in this connection Before passing to the second part of this Report, I must refer to the question of the change in head-form observed in the eastern parts of Crete when the Minoan population is compared with the modern one Whether it be armenoid or illyrian, an intrusive element seems accountable for the observed change The possibility of an evolutionary change whereby dolichocephalic ancestors were succeeded by broader-headed descendants is not indicated—and, indeed, is contra-indicated If high altitudes tend to produce brachycephalic proportions, Crete is an exception to the rule But this aspect of the subject can be discussed so exhaustively by Mr Hawes that I need do no more than mention it in this place

PART II —*The Craniology of the Ancient Inhabitants of Palaikastro and its Neighbourhood* (with an Appendix containing detailed accounts of all the ancient crania examined in 1903)

On the Craniology of the Prehistoric Inhabitants of Crete.

In the report furnished by me to the Cretan Committee in 1903, I gave a summary of the results of my measurements of the human crania in the Museum at Candia Those crania comprised a series of sixteen specimens from an ossuary of Minoan antiquity at Palaikastro In the course of my work at Palaikastro a good many more crania came to light, and together with those from Patema and Agios Nikolaos, a collection amounting to about one hundred was available for study

These ancient Cretans showed a great preponderance of dolichocephali, and indeed it is fair to say that they establish the fact of this preponderance for the epoch they represent But the mesaticephalic and brachycephalic elements are not negligible, and the present report deals with the latter, viz , the brachycephali In the light of Mr Hawes' work (to which reference is made in Part I of this report), it became urgent to examine the brachycephalic crania of the Minoan series as minutely as possible

I have appended to this account a series of notes made by me in 1903 on the specimens under consideration, but I have divided the Appendix into two parts, having segregated from the rest all crania

[5] *Cf.* Hawes, *Annual of the British School at Athens*, *loc cit* , p. 279.

with proportions in any way suggestive of brachycephaly It is convenient to submit the notes made on all the specimens, although those relating to the broader crania are chiefly in question here

The crania thus set aside for special notice are nineteen in number I hasten to add that this does not contradict the estimate of the percentage (8 55) of brachycephali recorded in my earlier report The method adopted here has been to pick out all crania with a breadth-index of 80 or more, as well as those having a maximum transverse diameter of 143 or more Some of the latter are not brachycephalic, and others are so fragmentary that they do not provide data both of length and breadth These fragmentary crania could not be included in the statistics of 1903, and indeed their exact cephalic indices are matters of surmise The nineteen specimens thus set aside include all the brachycephalic crania at my disposal But out of the nineteen only six demand special consideration here It is a matter for regret that in Crete the sites providing the most reliable evidence of the circumstances of interments are exposed to a climate so different from that of Egypt Considering the destructiveness of alternate phases of damp and dry atmospheres, it is a matter for satisfaction that any crania have been preserved in such a locality as Roussolakkos

The six crania in question are numbered on my system as follows: 2D, 19D, 25D, 48D, 105D, 112D Of these, Nos 19D and 25D must be considered apart, for they are assigned to the Mycenæan age or later The rest are ' Minoan ' or earlier The following Table III. gives their chief dimensions —

Table III

Skull No	Locality	Antiquity	Sex	Breadth Index	Length in mm	Breadth in mm	Remarks (1903)
2D	Palaikastro	Minoan	♂(?)	81 5	178	145	' armenoid '
19D	Zakro	Mycenæan	♂	81 7	175	143	' curvo-occipital ' type (1911) *
25D	?	late Mycenæan	♂	81 2	186	151	'curvo-occipital' type (1911)
48D	Palaikastro	Minoan	♂	83 7	178	149	distorted post-humously
105D	Patema	,,	♀(?)	83 2	167	?139	flattened occiput
112D	,,	,,	?	83 6	?165	?138	very fragmentary

* Cf Toldt, *Mitt der anth Gesellschaft in Wien*, Band 39–20, 1909–10

The specimens 2D, 19D, 25D, and 105D alone afford reliable information I have already noticed No 2D in sufficient detail A sketch (made in 1903) of this specimen is reproduced herewith (fig 1), together with a tracing of the vertex view (fig 2) No 105D is of similar antiquity to No 2D, and, like that specimen, has a flattened occiput

Inasmuch as both specimens are short rather than broad, the application of the term armenoid is further justified The corresponding heads would have provided cephalic indices of about 83 5 (2D) and 85 6 (105D) respectively

The two crania of post-Minoan antiquity resemble each other in presenting a curved occipital surface, not a flat one Otherwise they

are not dissimilar in point of index But one of them (19D) is a short brachycephalous skull, the other is long No 19D may be claimed as a further addition to the stock of armenoid specimens, whereas No 25D

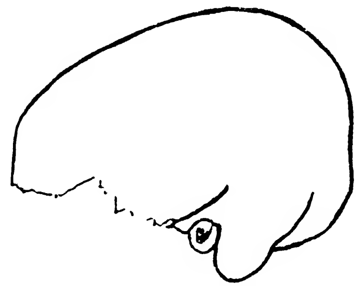


FIG 1.—Sketch of an 'armenoid' skull (No 2D) from a Minoan cemetery at Roussolakkos, Palaikastro, Crete

is rather to be grouped with the 'dorian' or 'illyrian' type recognised by Mr Hawes as distinct from the preceding But I lay no special stress on this point at present On the whole it appears that Eastern

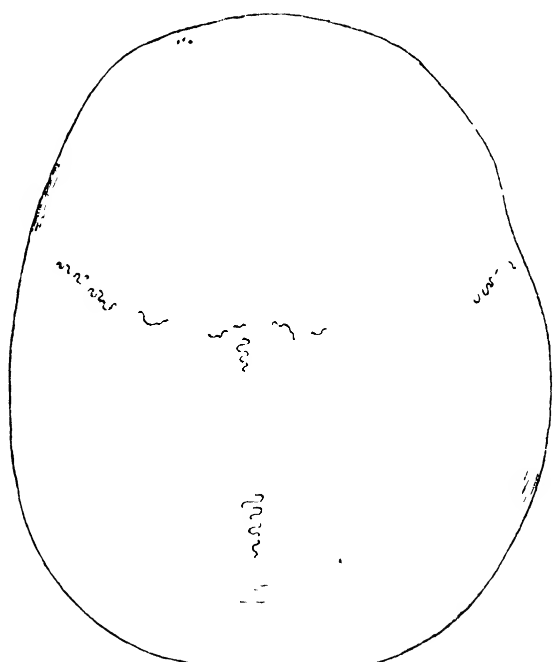


FIG. 2—A skull (No 2D) from Palaikastro; Norma verticalis ($\times \frac{1}{2}$).

Crete has thus provided evidence of the existence (in that region) of the armenoid type of head-form during the Minoan period, and indeed in its earlier part.

It is convenient to consider here the question whether there is other evidence to the same effect (Probably Mr Hawes has data, but I must write in ignorance of these) Of well-authenticated examples, I would cite the series of skulls described by the late Professor Mosso He measured nineteen crania referred to the Minoan period in Crete Some of the crania were found near Palaikastro Measurements are given by Mosso in his work entitled ‘ The Dawn of Mediterranean Civilisation ’[6] Of nineteen crania, four provide a breadth index of 80 or upwards, and are therefore brachycephalic The data are reproduced in Table IV

Table IV

Professor Mosso's Data Cretan Crania of the Minoan Period

Site	No of Specimen	Head Length	Head Breadth	Cephalic Index
Gournia	2	164	138	84 1
,,	3	166	136	81 9*
Palaikastro	11	176	141	80 1
Knossos	13	178	145	81 5

No records of sex or age are provided

* Erroneously given by Mosso (*op cit*, p 410) as 89 9

These data give no definite information as to the existence or otherwise of the armenoid type But we may at least note that the brachycephalic element is here present in an appreciable proportion (21 per cent), and further that these brachycephali are short rather than broad

It is noteworthy, however, that Professor Mosso assigns even the most brachycephalic cranium to the Mediterranean race, on the remark able ground that such head-forms are found in Egypt and in North

Table V

—	Locality	Epoch	Sex	Head Length	Head Breadth	Cephalic Index	Author	Remarks or Reference Number
I	Sicily	Neolithic	f	170	139	81 8	Sergi	No 1931
II	,,	,,	f	171	147	87 0	,,	No 1933
III	,,	Eneolithic	m	(ab	out	88 0)	Giuffrida-Ruggeri	No 2766
IV	,,	,,	m	170	145	85 3	Sergi	No 2231
V.	,,	Bronze	m	174	147	84 5	,,	No 2228
VI	Sardinia	Eneolithic	m	173	147	85 0	,,	No 11
VII	,,	,,	m	185	151	81 6	,,	No 25
VIII	,,	,,	f	174	143	82 2	,,	No 33
IX	,,	,,	m	176	145	82 4	,,	No 34
X	,,	,,	m	178	145	81 5	,,	No 44
XI	,,	,,	m	170	146	85 4	,,	No (II) 17
XII.	Corsica	Bronze	m	?	?	81 97	Chantre	No 1
XIII	,,	,,	f	?	?	81 98	,,	No 2
XIV.	Antiparos	‘ Early Ægean ’	—	178	144	80 9	Garson and Bent	—

Note —It is to be remarked that the evidence of distinct occipital flattening in these skulls is not recorded, or is but vaguely indicated in the descriptions. But the illustrations suggest that it is present in some cases at least

[6] English translation, by Miss Harrison, p 410.

References to Literature.

1. *Sergi* 'Di alcune varietà umane della Sardegna,' 1892.
2. „ 'Crani antichi di Sicilia e di Creta,' 1895
3. „ 'Crani preistorici della Sicilia,' 1899
4. „ 'Crani antichi della Sardegna,' 1906
5. *Giuffrida-Ruggeri* 'Antropologia fisica dei Siculi eneolitici'
6. „ 'Contributo all' antropologia fisica delle regioni dinariche, &c'
7. *Chantre* 'Assn franç. pour l'Av des Sciences' Ajaccio, 1901.
8. *Garson* 'Journal of Hellenic Studies,' Vol V, p 58

For numerous references, see Ripley, 'The Races of Europe,' and 'Bibliography' Brachycephalic crania are recorded from various localities in N Africa, and even in the Canary Islands.

Africa For the moment it will suffice to note the records and to disregard the conclusion as to the origin of these brachycephalic crania For Egypt I must of course refer to the publications of the various

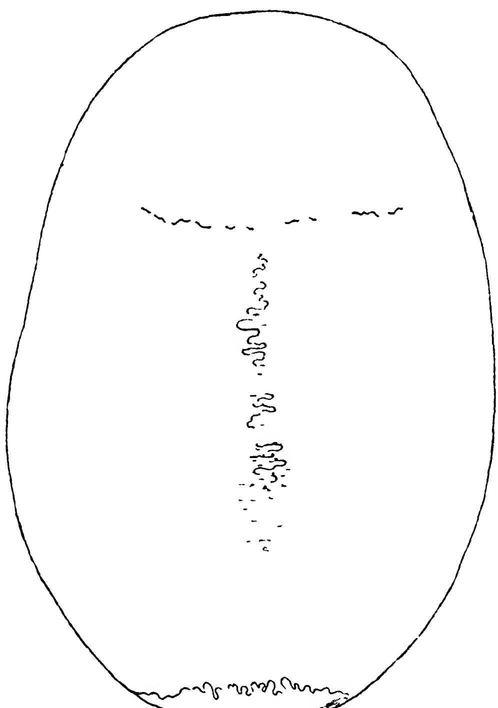


FIG. 3—A skull (No 8D) from Palaikastro, Norma verticalis ($\times \frac{1}{2}$)

surveys so fully elaborated by Professor Elliot Smith and his staff The early occurrence in Egypt of 'armenoid' skulls is now well known

I have several records for other parts of the Mediterranean area, but I must be content to indicate these without further discussion

Table V. contains data which are perhaps not well known to English writers, although the date of publication is not recent.

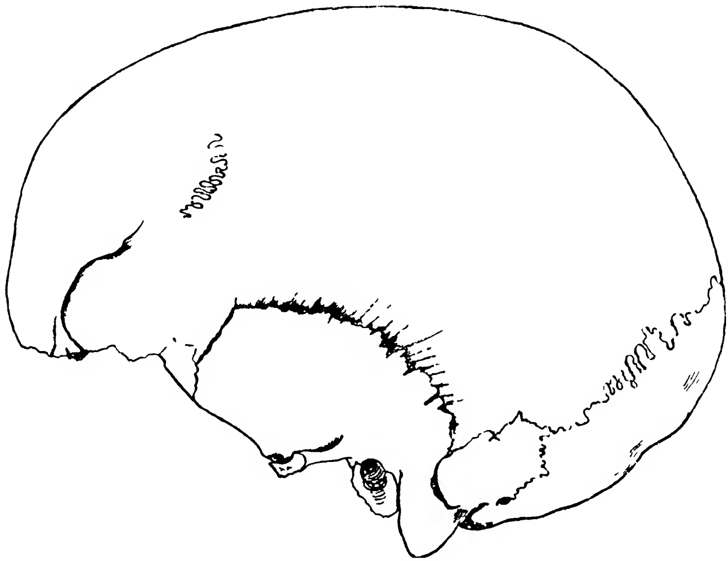


FIG 4 —A skull (No 8D) from Palaikastro; Norma lateralis (× ½)

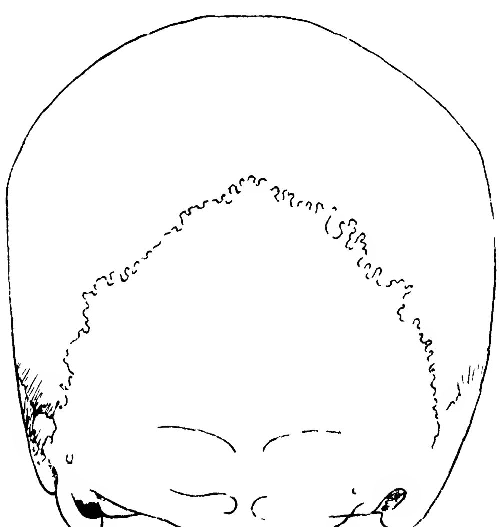


FIG 5 —A skull (No 8D) from Palaikastro; Norma occipitalis (× ½)

The crania numbered I, II, and III in Table V are very similar to the early Cretan brachycephali, moreover, the photographs in the

original memoirs [7] at least suggest that the term armenoid is applicable again I might add that the frequency of brachycephali in the eneolithic Sardinian series is in strong contrast with the variety of that type among modern inhabitants of Sardinia It would almost seem as though the brachycephalic type had been 'bred out,' or that it never established a footing in Sardinia, which is very different from Crete therefore

The majority of writers appeal to invasions and migrations to account for the presence of these ancient brachycephalic individuals Moreover the invasions are said to have occurred as far back as the neolithic period, and as for their source, that is supposed to be Eastern, with a course through Asia Minor in the cases considered

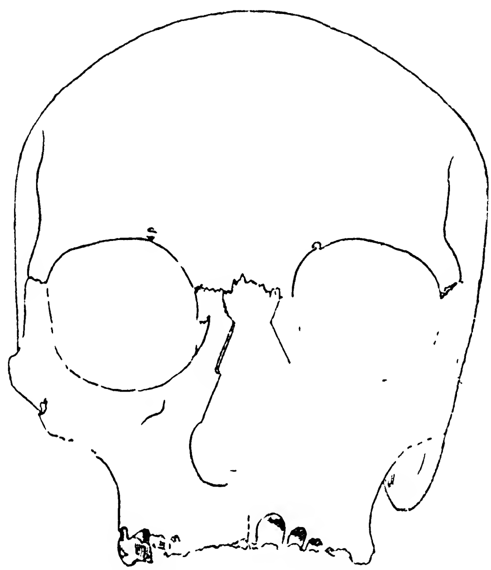


FIG 6—A skull (No 9D) from Palaikastro; Norma facialis ($\times \frac{1}{2}$)

Against such opinions we must set that of Professor Giuffrida-Ruggeri He admits invasions only during the more recent periods He insists on the extreme antiquity of the brachycephalic type as an indigenous form in Western Europe He regards it as autochthonous, and its appearance he ascribes to the effects of environment This he supposes to have been influential from the very earliest times

To discuss these alternative views is not possible here But reference must be made to the very valuable paper (by Professor Giuffrida-Ruggeri) on the physical anthropology of the Dinaric and Danubian regions

The brachycephalic Cretan crania of Mycenæan antiquity (Nos 19D and 25D) may well deserve discussion in connection with Bronze Age

[7] *Cf* footnote to Table V.

invasions But they may be relics of an earlier invasion, such as that held responsible for the Minoan brachycephali

My note-books contain descriptions of certain ancient Cretan crania referable to the Geometric and later periods But though I have added the descriptive notes to the Appendix, I shall not discuss those specimens in the present report The figures attached to this section are as follows One skull from Palaikastro (8D), of typical Mediterranean

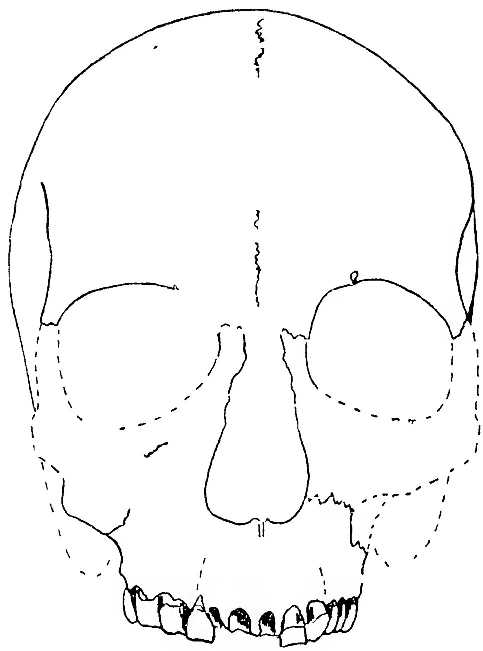


FIG 7—A skull (No 12D) from Palaikastro, Norma facialis (× ½)

form, is represented in three views (figs 3, 4, and 5) The facial view of two other skulls (9D and 12D respectively) is shown in fig 6 and fig 7

APPENDIX A—*Ancient Cretan Skulls with Breadth Index of* 80 *or upwards, or with Maximum Cranial Breadth of* 143 *mm or more* (Detailed notes copied from note-books—W L H D, Feb. 1903)

2D. *Palaikastro* (*cf* figs 1 and 2)—Calvaria, consisting of frontal, parietals, temporals and occipital bone The base, the facial bones, and the mandible are absent This is in some ways the most interesting skull of the series (viz those then known, being indicated as Nos 1D to 13D inclusive), presenting as it does an example of a distinctly brachycephalic form in a series where dolichocephalic proportions are immensely preponderant

General condition very fragile, surface slightly grooved by rootlets of plants

Sex probably male, though this must remain uncertain.
Age advanced, but not senile, the sagittal, coronal, and lambdoid sutures are closed by synostosis
Norma verticalis uniformly rounded and of a low degree of brachycephaly, it was almost certainly cryptozygous
Norma lateralis brow-ridges not prominent, frontal curve rises abruptly and attains its highest point 4 or 5 cm behind the bregma (*cf. Armenoid-typus of v Luschan*), slight annular compression round coronal suture (this is in favour of female sex) *The occipital region is generally flattened*, but actually the surface is interrupted by a series of slight elevations and depressions
Norma facialis transverse arc regular and fully rounded, the cranial width is great in the region of the alisphenoid
Norma basilaris glenoid fossæ deep, tympanics imperforate
Norma occipitalis contour rounded, mastoids appear large, and project strongly downwards

13D. *Palaikastro* —A calvaria, without a base, face, or mandible

Sex male.
Age advanced, yet not senile
General remarks the skull is rather larger, and is distinctly broader than the preceding specimens (No 2D had not been unpacked then) The parietal eminences stand out clearly and give the skull a rhomboid appearance, the frontal region is less well developed, and the parietal region is better developed than in the other skulls, which are longer and narrower It resembles some Polynesian crania It tends towards mesaticephaly (the index is 74 2)
Norma verticalis length moderate, outline rhomboidal, with marked parietal eminences, skull was probably just phænozygous Synostosis almost complete in the sagittal suture and far advanced in the coronal suture Muscular ridges are indistinct on account of the 'weathering' of the bones
Norma lateralis very prominent brow ridges, and large massive mastoid processes, the external occipital protuberance is on the contrary inconspicuous The median sagittal curve attains its maximum elevation about 5 cm behind the bregma There is an area of flattening in front of each parietal eminence, the calvaria is therefore slightly 'ill-filled'
Norma facialis the transverse frontal arc is well rounded, but the transverse arc behind the bregma is interrupted, and a slightly scaphoid outline results
Norma basilaris the tympanics are imperforate, endocranial synostosis is far advanced
Norma occipitalis the outline is pentagonal large elongated mastoid processes extend downwards clear of the cranial base

19D. Σαρχος, *Mycenæan* —A fragile skull with its mandible, the outer margin of the right orbit is fractured

Sex: male
Age adult—synostosis is advanced in the sagittal suture near the obelion, and in the coronal suture just above the pterion
Norma verticalis brachycephalic (breadth-index 81 7), cryptozygous, and slightly plagiocephalic, owing to flattening on the right side
Norma lateralis brow-ridges moderate, profile orthognathous, slight occipital, renflement, mastoid processes small
Norma facialis the plagiocephalic character is very evident in the form of the transverse cranial arch, the face is broad, the orbits megaseme, the nasal aperture leptorrhine, with slight prenasal grooves
Norma basilaris the palate is elliptical, both tympanic bones are perforated, the last molar teeth are small, their three roots being fused into one in the upper jaw. The third lower molars have two roots (as usual).
Norma occipitalis: the contour is pentagonal, the plagiocephalic asymmetry not being noticed

25D. *Between the Mycenæan and Geometric Periods*.—A skull with other parts of the skeleton, 'found in a coffin.' The skull is nearly complete, the mandible accompanies it and has a bigonial diameter of 106 mm. The skull is very large in comparison with the others; it is brachycephalic.

Sex: male.
Age.: senile; synostosis is advanced, but nearly all the teeth are present; the last molars are much smaller than the others.
Norma verticalis: the contour is bluntly oval; muscular ridges are distinct. The prognathism is 'subnasal' and 'alveolar,' not 'dental.'
Norma lateralis: the brow-ridges are distinct but not massive; the face is slightly prognathous. The prognathism is 'subnasal' and 'alveolar,' not 'dental;' the median sagittal curve culminates at the bregma, and continues as a plateau for nearly 4 cm. before descending to a moderate occipital renflement. The mastoid processes are of moderate size.
Norma facialis: the transverse cranial curve is flattened above; the margins of the nasal aperture become indistinct near the spine.
Norma basilaris: the palate is elliptical; the glenoid fossæ are deep; the tympanic bones are imperforate.
Norma occipitalis: the contour is rather pentagonal than circular. *The skeleton* bears signs of spondylitis; the femur has a stout shaft and very prominent linea aspera. The index of platymeria is 89.4 (the bone is *not* platymeric). The right tibia measures 346 mm. and has a platycnemic index of 69.8. The left tibial index is 73.1.

48D. *Palaikastro*.—Calvaria with part of face; important, as it is broader (cranially) than most (149 mm.); brow-ridges moderate; calvaria distorted by pressure.

53D. Probably a female; important, because rather broader than most of the rest; brow-ridges insignificant; distinct occipital renflement; cranial vault culminates at obelion; base fractured and distorted.

58D. No remarks; only three measurements made, viz., maximum breadth, 147; length, 187; breadth-index, 78.6.

60D. A small mesaticephalic (it proved to be brachycephalic) female skull, young adult; typically feminine; brow-ridges minimal (see sketch); no occipital bone remains.

85D. Senile; it is very prognathous.

93D. A young skull (not in averages), third molar teeth not yet cut; mandible *in situ*; important, as being rather broader than most (173 × 137); breadth-index, 79.6.

97D. Important as being a broad skull, but very fragile and fragmentary; sex, male.

105D. *Patema* (*near Palaikastro*).—An adult and brachycephalic skull; sex uncertain, but probably female; occipital region flattened, but otherwise 'well filled'; synostosed sagittal suture at obelion; small brow-ridges. Quite distinct from the ordinary type. [This specimen was not included in the averages, as there was a doubt as to its breadth. This seemed to be 139 mm.; the length being 167, the resulting breadth-index would be 83.2. Moreover it is a *short* skull rather than a *broad* one, and it is therefore more likely to represent the 'armenoid' than the 'illyrian' type of Hawes.]

112D. *Patema* (*near Palaikastro*).—A broad skull with mandible, very fragmentary. [This skull provided no measurements for the

averages it seems to have measured about 165 mm × 138 mm, this would give a breadth-index of about 83 6 Again this would be more like the 'armenoid' than the 'illyrian' type of Hawes]

113D. *Patema* (*near Palaikastro*) —A very large adult male skull, very fragmentary; perforated by rootlets of shrubs, brow-ridges small, occipital renflement not marked [It is introduced here on account of the comparatively large figure representing its breadth, the measurements are—length, 199, breadth, 146, breadth-index, 73 4]

123D. *Patema* (*near Palaikastro*) —A large adult male skull, sagittal suture closed by synostosis, brow-ridges moderate, occipital renflement moderate, mastoids of moderate size, high frontal arch, orbits microsemic, this skull is rather broader than most in this series

139D. *Palaikastro* —A large adult male calvaria occipital renflement moderate, the front part of the calvaria having been broken away, a false impression of shortness is given The skull was probably long

143D. A distinctly broad ovoid skull, adult male, moderate size complete sagittal synostosis, neither brow-ridges nor occipital renflement marked

145D. An aged male skull of moderate size, brow-ridges marked, occipital renflement not marked, prognathous Complete sagittal synostosis This skull is much more like a certain Egyptian form than any yet seen, but the nasal bones are not negroid, although the nasal aperture is wide This specimen and No 143D are distinct from the prevailing type, they are broader and rather byrsoid They probably constitute a mesaticephalic sub-type

154D. *Agios Nikolaos* —Fragmentary skull of a child of about six years of age, complete premature synostosis of the sagittal suture, without apparent deformation of the cranial form The specimen is, however, actually broader than most of the adult crania

Appendix B —*Ancient Cretan Skulls other than the Brachycephalic and Broad Specimens described in Appendix A*

Brief descriptions of the crania found in East Crete in 1903 Note that in the last series (ten or more in number) the descriptions have been published already[8] and need not be repeated here For the most part the descriptions are arranged in the numerical order of the specimens But from the whole series under review nineteen specimens have been removed, and the descriptions of these are brought together in the preceding sub-section of this part of the report

System of Numeration

Group I.—Specimens obtained previously to 1903 and in that year examined in the Museum at Candia by W L H D

1D–13D incl, 21D, 22D, 23D *Palaikastro* (ossuary at *Roussolakkos*) · continued as 26D, &c
14D, 14aD. *Præsos*
15D. No information
16D, 17D, *Zakro* (Hogarth); 16D, 'later', 17D, 'earlier' period
18D, 18aD *Modern Cretan* crania Candia, Vori, Agia Triatha, &c.
19D, 20D (Asites), 20aD (Asites), *Mycenæan* period

[8] *Cf. Annual Report of the British School at Athens*, 1903.

4D, with skeleton From a larnax (locality not given) *just anterior to Geometric Period*
25D, with skeleton From a tomb *Between Mycenæan and Geometric Periods*
26D a, Knossos *Mycenæan*
27D a, Gournia *From* tombs (not larnakes)

Group II—Excavations at Roussolakkos &c in 1903

26D to 34D[9] Roussolakkos, Ossuary, Compartment I
35D to 44D „ „ „ II
45D to 64D „ „ „ III
65D to 84D Provided for Compartment IV, but no crania obtained here.
85D to 104D Roussolakkos, Ossuary, Compartment V
105D to 124D *Patema*
125D to 146D. *Roussolakkos Ossuary, No* 2
150D to 160D *Agios Nikolaos*

1D. *Palaikastro*—A calvaria consisting of the frontal, parietal, and temporal bones the cranial base, the facial bones, and the mandible have been destroyed

Sex probably male
Age adult
General condition fragmentary and extremely fragile, the indications are of small size and feeble musculature
Norma verticalis long and narrow, this effect is heightened by posthumous lateral compression The cranial sutures are open
Norma lateralis the lateral flattening is attended by an increase in vertical height The brow ridges are not prominent, nor are the parietal ridges The mastoid processes are of moderate size
Norma facialis the posthumous compression has increased a pre existing tendency to scaphocephaly
Norma basilaris the glenoid fossæ are of moderate depth, the tympanic bones are imperforate
Norma occipitalis the contour is not distinctly pentagonal, the angles being rounded off

3D.—This specimen consists of a few fragments of the cranial vault The skull was probably dolichocephalic, the dimensions of the plaster casing (now removed) indicate such proportions

Sex probably female
Age adult but not senile, although the sagittal suture has commenced to close
The *general indications* are of slight muscular and physical development

4D.—A calvaria, consisting of frontal, parietal, occipital, and temporal bones The base, the facial bones, and the mandible have been lost

Sex male
Age fully adult, but not senile, synostosis in the three chief sutures.
Norma verticalis a long ellipsoidal skull, probably cryptozygous
Norma lateralis massive brow-ridges, stout zygomatic arches, large massive mastoid processes, at the inion a distinct transverse torus culminates in a median spinous protuberance The median sagittal curve rises gradually from the ophryon to culminate 5 cm behind the bregma
Norma facialis the transverse arc is uniformly rounded, with very slight bilateral postbregmatic flattening

[9] For each compartment or ossuary a distinctive range of numbers was set aside, the range being ten or twenty units Where the special number of skulls was not actually obtained, the numbers remain as blanks, so that when 160D Agios Nikolaos is mentioned, it does not follow that the total count of ancient Cretan skulls examined amounted to 160. The numbers are inclusive.

Norma basilaris no observations possible.
Norma occipitalis the transverse arc is regular, the parietal eminences not standing out, the massive character of the mastoid processes is again evident

5D.—A calvaria, consisting of the frontal, parietal, temporal, and occipital bones, with small portions of the alisphenoids The specimen is very fragile and fragmentary

Sex probably female
Age. adult
Norma verticalis an extremely dolichocephalic specimen of ellipsoidal form, hardly any lateral crushing has been sustained The uniformly smooth surface and the faintness of the ridges for muscular attachments suggest a female skull The sagittal suture is commencing to close The specimen was probably just cryptozygous
Norma lateralis the brow ridges are inconspicuous, the median sagittal curve is continuous and regular from the nasion to the opisthion, culminating about 5 cm behind the bregma The zygomatic arches are feeble and the mastoid processes small
Norma facialis the relatively great height of the cranial vault is at once noticed, the transverse arc is very regular, but in the post bregmatic region there is a suggestion of scaphocephaly
Norma basilaris the tympanic bones are imperforate
Norma occipitalis the contour is somewhat pentagonal with much rounded angles

6D.—A calvaria, consisting of the frontal, parietal, occipital, and temporal bones To this (anteriorly) part of the right side of the facial skeleton is attached, consisting of malar, maxilla, and sphenoid The base, the left side of the face, and the mandible are absent The general condition resembles that in most of the preceding examples

Sex male
Age adult, well advanced towards senility, many teeth lost, there is much synostosis in the lambdoid and sagittal sutures
Norma verticalis the cranium is elongated and elliptical, it is uniformly rounded, with distinct though comparatively feeble muscular ridges It was probably cryptozygous
Norma lateralis the brow ridges are prominent for this series (in which, however, numerous female skulls are included) The median sagittal arc is flattened at the bregma no distinct occipital renflement appears, there is a prominence at the inion, and the mastoid processes are massive The facial profile was probably orthognathous
Norma facialis the transverse cranial arc is uniformly rounded, the orbit has micro- or meso seme proportions The nasal aperture is leptorrhine
Norma basilaris the right alveolar arcade is edentulous, and the left tympanic bone is imperforate
Norma occipitalis the contour is pentagonal, the mastoids project markedly downwards The lambdoid suture is partly closed by synostosis

7D.—A cranium without face or mandible

Sex. male
Age adult, the cranial sutures are synostosed but chiefly on the endocranial aspect
The surface of the cranial vault is grooved by rootlets of plants
Norma verticalis an elongated ovoid skull
Norma lateralis · the cranium is flat, brow-ridges are massive and prominent; the median sagittal curve culminates 3 cm behind the bregma The occipital renflement is slight but distinct At the inion a transversely directed torus is found. The mastoid processes are of moderate

Norma facialis : scaphocephaly is distinct, with marked areas of flattening on each side of the sagittal suture This gives an 'ill-filled' appearance to the specimen

Norma basilaris no observations, the base being absent

Norma occipitalis the contour is pentagonal, the small vertical height and the consequently flat appearance of the cranial part of the skull, is again remarked

8D (Figs 3, 4, 5) —A cranium without the face or mandible, very brittle texture, the base has been destroyed

Sex. female

Age adult, but not senile, synostosis is extensive in the coronal as well as the sagittal suture

General features typically feminine

Norma verticalis very long and narrow, no irregularities of surface; 'well-filled' aspect

Norma lateralis the cranial cavity is of moderate height; brow-ridges not prominent, forehead high, the sagittal curve culminates 2 cm behind the bregma, occipital renflement slight, the mastoid processes are small, the alisphenoid joins the parietal at the pterion

Norma facialis the transverse arc is regular and rounded, the facial width was evidently very small

Norma basilaris the great length is again apparent, the left tympanic bone is perforated

Norma occipitalis the contour is rounded, not pentagonal

9D (Fig 6) —Cranium with part of face, mandible absent, base destroyed, surface much pitted and grooved by rootlets

Sex female

Age adult, cranial sutures are not synostosed

Teeth three molar teeth (right, M^1, M^2, left, M^2) remain, the sockets for the roots of the last molar teeth (M^3) show that these were smaller than the other molars

General features typically feminine, resembles a skull from Erganos figured by Sergi

Norma verticalis the cranium is long, narrow, and rather byrsoid Large but distinct parietal eminences contribute to the latter character, muscular attachments hardly recognisable

Norma lateralis orthognathous, slight brow-ridges, distinct area of flattening along vertex from 2 cm in front of bregma to 4 cm behind that point, slight occipital renflement, conformation of occiput is feminine, no ridges, mastoid processes small, at the pterion the alisphenoid joins the parietal bone; the cranium is tapeinocephalic

Norma facialis the transverse arc is rounded, the face is narrow, the maxillæ small, the orbits are megaseme, the nasal aperture mesorrhine with small sub-nasal grooves, the canine fossæ are deep

Norma basilaris the great length of the skull is apparent, the palate is long and narrow, the glenoid fossæ are deep, and both tympanic bones are imperforate

Norma occipitalis the contour is nearly pentagonal, owing to the prominence of the parietal eminences

10D.—A cranium without the face or mandible, the specimen has been reconstructed from fragments

Sex female, muscular ridges inconspicuous

Age fully adult, not senile

Norma verticalis : dolichocephalic, just cryptozygous; full synostosis in sagittal, coronal, and lambdoid sutures, very slight 'annular' compression near coronal suture (clinocephaly).

Norma lateralis : brows not prominent; forehead vertical; the median sagittal arc culminates about 4 cm. behind the bregma; distinct occipital bulging; mastoid processes small.

Norma facialis: the transverse arc is uniformly rounded so that no appearance of the 'ill-filled' type can be detected
Norma basilaris: the tympanic bones are imperforate.
Norma occipitalis the general contour is nearly circular, owing to the small development of parietal eminences and mastoid processes
Endocranium synostosis complete, there is a well-developed internal occipital protuberance, not marked for the torcular.

11D.—A reconstructed cranium without face or mandible

Sex. female.
Age adult, but not senile
General description. a delicate cranium with feebly developed muscular impressions.
Norma verticalis the form is slightly byrsoid, owing to the distinctness of the parietal eminences, no synostosis in sagittal or coronal sutures
Norma lateralis: insignificant brow-ridges; forehead rises abruptly, basi-bregmatic height relatively small—i e, tapeinocephalic proportions are present; occipital renflement slight
Norma facialis: the transverse arc is well rounded.
Norma basilaris: the glenoid fossæ are distinctly shallow, the tympanic bones are imperforate
Norma occipitalis: the transverse contour is nearly circular—*i.e*, feminine In fact, all the characters of the specimen proclaim this as its sex

12D (Fig 7)—The specimen is so brittle that it is impossible to free it from adherent soil, it consists of the cranium and face, with part of the mandible.

Sex ? female.
Age: adult.
Norma verticalis: metopism (persistence of the inter-frontal suture) is present, but the metopic suture is obliterated near its mid-point An elongated elliptical contour is seen, there is a remarkable band of flattening about 3 cm wide, extending backwards from near the obelion
Norma lateralis brow-ridges inconspicuous, the frontal bone rises steeply, the median sagittal contour culminates at the bregma and is flattened from the obelion backwards The flattening looks as though a compress had been applied in the situation indicated Orthognathism is very distinct There is a very slight occipital renflement
Norma facialis the face is distinctly leptoprosopic[10], the transverse cranial arc is uniformly rounded in a plane, anterior to the bregma The orbit is megaseme, the nasal aperture narrow There is practically no fronto-nasal depression.
Norma basilaris the palate is small and of parabolic contour.
Norma occipitalis the contour is pentagonal, slightly flattened areas are seen on each side of the sagittal suture.

14D. *Præsos*: ? *Hellenistic Period*—A much-disintegrated skull with the mandible, the adherent soil renders the taking of measurements almost impossible

Sex: ? female.
Age: adolescent, but nearly adult, the wisdom teeth are just about to emerge from the jaws.

14aD. *Præsos* ? *Hellenistic Period*—A skull and mandible; extremely fragile and encrusted with earth, zygomatic arches broken

Sex: ? female
Age: adult.
Norma verticalis: elongated and ellipsoidal.

[10] All the specimens that give evidence on this feature provide the same indication as 12D.

Norma lateralis prognathism is the chief characteristic It is 'sub-nasal' and not suggestive at all of a negroid type. The teeth are small and do not project, there is a slight occipital renflement, otherwise, the median sagittal contour is regular The mastoid processes are small, and muscular impressions are scarcely recognisable.
Norma facialis the transverse arc is uniformly rounded. The face is leptoprosopic, with megaseme orbital apertures and a leptorrhine nasal aperture, the breadth of the brain-case in the region of the pterion is considerable, and it shows that the skull was cryptozygous.
Norma occipitalis . the contour is rounded or circular.

15D. *Of uncertain antiquity* —A skull with other bones The antiquity of these specimens is quite uncertain No data are available as to the locality whence they were derived The collection comprises a cranium, two mandibles, a very long sacrum (index just under 83), a femur of the left side (with a small 'third' trochanter), a tibia, a humerus of the left side (perforation of the olecranon fossa), a radius and various odd vertebræ The cranium is fragile and apparently not ancient

Sex male
Age adult, the sagittal suture is closed at the obelion, and there is also synostosis in the coronal suture just above the pterion
Norma verticalis the skull is mesaticephalic, and of ovoid form; it is cryptozygous
Norma lateralis the brow ridges are prominent, the profile orthognathous; the median sagittal arch culminates 4 cm behind the bregma, there is a very slight occipital renflement, the zygomatic arches are stout and the mastoid processes massive
Norma facialis the face is broad and the transverse cranial arc uniformly rounded
Norma basilaris the palate is of elliptical form, the last upper molar tooth (the left) is the smallest of the series, both tympanic bones are perforated; there is an ossified ligament of Civinini on each side, the glenoid fossæ are deep
Norma occipitalis the contour is pentagonal

16D. *Zakro* ('Hogarth') —Found in a cave with many fragments of skulls and other bones This specimen appears to be of recent date The calvaria of a child of about six to seven years of age It is brachycephalic, the measurements are only approximate, however; they are as follows—length ? 164, breadth 133, cephalic index 81 1

17D. '*Early*' *Zakro* ('Hogarth') —Possibly from a cave A cranium without the mandible, the state of preservation is fairly good; it has been varnished, and thus disintegration has been arrested No marks of rootlets seen

Sex female, of feminine aspect throughout.
Age adult
Norma verticalis the contour is of the elongated ellipsoidal variety; the principal sutures are just about to close.
Norma lateralis the brow-ridges are small; the profile orthognathous. The forehead is high, for the frontal bone rises abruptly, the median sagittal curve culminating near the obelion and being somewhat flattened near the bregma. There is a slight occipital renflement. The zygomatic arches (broken) were slender. The vertical extent of the brain-case is small (tapeinocephalic)
Norma facialis : the transverse cranial arc is perfectly rounded; the face is small, the orbits microseme, the nasal aperture wide.

Norma basilaris: the palate is small and elliptical; the teeth (especially the last molars) are small, delicate, but not decayed, the tympanic bones are perforated.

Norma occipitalis: the contour is rounded, not pentagonal: all the features noted combine to indicate the female sex of the specimen.

18D. *Modern*.—Skull of a modern Cretan male. The chief interest of the specimen is that it reproduces on a feeble scale the features of a cranium from near Damascus, described by me (as of 'armenoid' form) in the 'Journal of the Anthropological Institute.' The skull is of moderate length only, and in norma verticalis the contour is 'byrsoid.' The occipital flattening so characteristic of the true armenoid skull is very slight here. The brow-ridges are heavy, the mastoid processes are large and they project anteriorly.

20D. 'Asιτες.' (*sic*).—A calvaria without base or facial bones, the left half of the mandible remains.

Sex: male.

Age: adult, synostosis is observed in the sagittal suture and also in the squamo-parietal suture.

Norma verticalis: the skull is of short ellipsoid form and mesaticephalic, at the ophryon a remarkable depression suggests the former presence of a sebaceous cyst in this situation.

Norma lateralis: brow-ridges moderately developed, the median sagittal curve culminates at the obelion, there is slight occipital renflement. The nasal bones are prominent.

Norma facialis: the transverse cranial arc is uniformly curved, this feature is present, even posteriorly to the bregma.

Norma basilaris: both tympanic bones are perforated.

Norma occipitalis: the contour is 'pentagonal.'

20aD. 'Asιτες.' (*sic*).—Occipital parts of skull with mandible.

Sex: female.

Age: young adult.

Norma verticalis: rhomboidal and elongated.

Norma lateralis: very distinct occipital renflement.

Mandible: teeth slightly worn, the last molars are the smallest. The mandible is narrow and suggests leptoprosopic proportions of the face.

21D. *Palaikastro*.—A calvaria comprising the frontal, two parietals, the occipital and right temporal bones. The face, base, and mandible are wanting.

Sex: ? male, the general indications are distinctly those of weak physical development.

Age: adult; synostosis commencing in the usual situation, viz., in the sagittal suture near the obelion, and in the lambdoid suture.

Norma verticalis: the contour is ovoid but elongated, the parietal eminences are scarcely distinguishable.

Norma lateralis: the brow-ridges are but slightly prominent, the frontal bone rises steeply. The median sagittal curve is flattened at the bregma, where indications of slight 'annular' compression are found. Occipital renflement is very marked, almost amounting to bathrocephaly. The skull was probably orthognathous and tapeinocephalic.

Norma facialis: the transverse cranial arc is uniformly rounded, even behind the bregma, the frontal width is small, the minimum being 90 mm.

Norma basilaris: synostosis is far advanced on the endocranial surface, the glenoid fossæ is deep and the tympanic bone not perforated.

Norma occipitalis: the contour is pentagonal rather than circular, but the angles are rounded.

22D.—A skull without the mandible, there is a large deficiency on the left side, the outlines of the nasal and orbital apertures had to be cleared by removing an adherent mass of soil

Sex. male.
Age adult.
Norma verticalis. the contour is that of a very long ellipse, which is regular and symmetrical The skull is just cryptozygous
Norma lateralis the profile is orthognathous, the brow-ridges are but slightly prominent, the frontal arc rises abruptly above them, at the bregma a slight flattening occurs, and the sagittal curve culminates about 5 cm behind this Occipital bulging is small in amount The mastoid processes are large
Norma facialis the cranium is slightly but certainly scaphoid, the face has the leptoprosopic proportions characteristic of the majority of this series, the nasal aperture is narrow.
Norma occipitalis the form of the contour is rather circular than pentagonal, but does not conform precisely to either description

23D.—A calvaria, consisting of the frontal, two parietal, the occipital, and the left temporal bones, the base is embedded in hard, dry clay, which forms a cast of the endocranial cavity

Sex male.
Age adult, synostosis is advanced in the sagittal suture
Norma verticalis a very long elliptical skull
Norma lateralis brow-ridges only moderately developed The median sagittal arc culminates 4 to 5 cm behind the bregma, occipital renflement is distinct
Norma facialis a slight but distinct degree of the scaphoid character is observed in the transverse cranial arc
Norma occipitalis the contour is pentagonal, the cranium being distinctly 'wall-sided'

24D. '*Just anterior to the Geometric Period*' (? late Mycenæan)—A calvaria with the skeleton from a larnax, the skeleton was in the contracted position It is extraordinarily brittle

Sex male
Age. adult, or senile
Norma verticalis the most interesting point is that the calvaria is nearly brachycephalic, synostosis of the cranial sutures is almost complete
Norma lateralis the brain case is rather flat, the brow-ridges are prominent; the median sagittal curve is flattened near the bregma Occipital renflement is slight, there is a marked occipital torus The mastoid processes are small
Norma occipitalis: the contour is pentagonal, the transverse occipital torus with the conceptacula cerebelli beneath it are prominent details of conformation
The limb bones are so delicate and slender as to suggest the female sex, but this is largely discounted by the brow-ridges and occipital torus. But in any case the senile changes obscure the general cranial features of value in determining sex

26aD. *Knossos* (*Mycenæan*)—Period probably about 1800 B C, found in a magazine beneath a vase, attributed to the earliest period of the palace to which a date can be assigned A calvaria, the base, face, and mandible are absent

Sex male
Age: adult; sutures open, denticulation not complex
Norma verticalis: elongated and elliptical; 'well-filled'

Norma lateralis: slight brow-ridges, distinct occipital renflement, muscular impressions minimal. The mastoid processes are small, the cranial height is not great; the specimen is thus tapeinocephalic. It resembles several of the Palaikastro skulls, and some others of Mycenæan antiquity; but it is not remarkably dolichocephalic

Norma facialis the transverse cranial arc is regular in front of the bregma; behind are slight parietal flattenings.

Norma basilaris capacious frontal sinuses; the tympanic bones are imperforate, the styloid processes are very small

Norma occipitalis the outline is pentagonal but the angles are rounded off

27aD. *Miscellanea*

1 *Gournia*.—A number of fragmentary limb bones were found at Gournia on March 23, 1903 These bones had been removed from tombs (not larnakes) of probably Mycenæan age, by the workmen under the direction of Miss Boyd (now Mrs Hawes) The bones are as a rule small The femora are pilastered, and there are two very platymeric examples, they have an 'external flange' Of the twelve tibiæ, two are platycnemic

2 *Kalybia*.—Fragments of limb bones from the larnakes discovered at Kalybia and excavated by Dr Xanthodides, have an appearance similar to the bones from Gournia

Cemetery (or Ossuary) No 1 (Excavations under supervision of W L H D, 1903)

PALAIKASTRO COMPARTMENT I

Skull 26D. In fragments

„ 27D Fragmentary, a large massive skull with prominent brows, very dolicho cephalic (206 × 141 Index 68 3)

PALAIKASTRO: COMPARTMENT II.

„ 35D A dolichocephalic skull embedded in gypsum for transport

„ 36D. A very dolichocephalic skull

„ 37D. Very fragmentary, measurements not in averages; they are approximately as follows length 164 mm, breadth 118 mm, index 72

„ 38D Cranium placed on its side, no other notes, save that it was measured and packed in gypsum for transport to Candia

„ 39D No notes; three measurements only.

PALAIKASTRO COMPARTMENT III.

„ 45D. A long oval skull, moderate brow-ridges, male (typical)

„ 46D. A small but adult female skull

„ 47D. A small (probably female) skull; dolichocephalic, brow-ridges insignificant; much compressed laterally

„ 49D. A very long, narrow male skull; elongated more than naturally by pressure; brow-ridges moderate, slight occipital renflement

„ 50D. Long skull of an adult male, slightly distorted, top broken in, moderate brow-ridges; slight occipital renflement

„ 51D A small dolichocephalic female skull, possessing the general characters of the series

„ 52D A small skull, apparently dolichocephalic, but so distorted by pressure as to preclude a confident statement.

„ 54D Probably female, long and rather rhomboid; brow-ridges slight, occipital renflement distinct; mastoids of moderate size.

„ 55D. Very perfect adult male skull, base somewhat distorted, mandible preserved; subnasal prognathism, otherwise typical features

„ 56D. A small female skull, interesting because it is a narrow skull compressed (posthumously) so as to appear broad

Skull 57D. A small male skull of the usual narrow type; brow-ridges distinct, but small, slight annular compression (coronal), very fragile.

„ 59D. A small narrow male skull, brow ridges moderate, occipital renflement slight, massive occipital torus

PALAIKASTRO. COMPARTMENT IV

No skulls found in 1903

PALAIKASTRO COMPARTMENT V.

Skull 85D Senile skull, it is very prognathous

„ 86D to 88D incl Crania too fragmentary and fragile for description

„ 89D This skull is remarkable for the presence of the first two vertebræ remaining in their natural position in regard to it

„ 90D No note taken

„ 91D Senile, ? also mollities ossium

„ 92D Typical of the series, slightly prognathous, prominent brow-ridges

„ 94D A skull of the usual type, female, small brow-ridges and moderate occipital renflement

„ 95D A small senile skull, probably female, brow-ridges minimal, distinct occipital renflement, lack of development in the vertical direction, the cranium therefore is tapeinocephalic.

„ 96D Occipital fragments only

„ 98D A small, narrow male skull, prominent brow-ridges, slight occipital renflement, mastoids large

„ 99D A typical elliptical male skull, moderate size, distinct occipital renflement, sagittal curve culminates near bregma

„ 100D A large skull of an adult male, narrow and elliptical, brow-ridges marked, distinct occipital renflement.

„ 101D A slightly scaphoid male skull of moderate size, brow-ridges marked, distinct occipital renflement.

„ 102D A male skull of moderate size, mastoids large; marked brow-ridges and distinct occipital renflement

Patema.

„ 106D A tapeinocephalic (flattened or cylindroid) skull, ? of male sex, dolichocephalic, brow-ridges small, marked occipital renflement, zygomatic arches slender, muscle-ridges feebly marked

„ 107D Very large adult male skull with face; brow-ridges well marked, occipital renflement not marked

„ 108D A small flattened adult female skull, brow-ridges not marked, occipital renflement marked

„ 109D No remarks; only one measurement (width) possible.

„ 110D ? male skull, compressed laterally, brow-ridges small; occipital renflement slight

„ 111D. An adult male skull; excessively fragile, small brow-ridges, distinct occipital renflement

„ 113D A very large adult male skull, very fragmentary, perforated by rootlets of shrubs, brow-ridges small, occipital renflement not marked. Length 199, breadth 146, B I. 73 4

„ 114D A large adult male skull, distorted by lateral pressure

„ 115D A large adult male skull, very fragile, distorted, and perforated by rootlets; face destroyed, moderate brow-ridges, slight occipital renflement.

„ 116D No remarks.

„ 117D. A long oval male skull of moderate size; complete sagittal synostosis; brow-ridges small, occipital renflement distinct, small mastoids; right side broken

„ 118D. A small female skull, long and ovoid; nearly complete sagittal synostosis, brow-ridges small, occipital renflement not marked

„ 119D A small female skull, elongated; slight annular constriction; brow-ridges small, occipital renflement not marked

„ 120D A moderately long ovoid male skull; brow-ridges marked; occipital renflement not marked.

Skull 121D. A large adult male skull; sagittal synostosis not far advanced, measurements made on skull *in situ*, brow-ridges small, occipital renflement marked.
„ 122D Remarks as for 121D.
„ 124D. A small ovoid female skull with its mandible, brow-ridges small; occipital renflement very marked, forehead 'high', right temporal bone depressed within skull.

Palaikastro, Ossuary No 2

„ 130D. An adult male skull of moderate size; brow-ridges moderate, occipital renflement moderate, mastoids massive
„ 131D An adult male skull of moderate size, brow-ridges pronounced, occipital renflement marked, a large tubercle at the inion, slightly scaphoid; slightly prognathous
„ 132D Skull of an adult male, similar to the majority of this series, specimen so crushed that only length could be measured
„ 133D. Calvaria of an adult male; fragmentary, moderate size, dolicho cephalic; no measurements
„ 134D. No remarks; evidently very fragmentary.
„ 135D. No remarks; evidently very fragmentary
„ 136D. Very fragmentary.
„ 137D. No remarks; evidently very fragmentary
„ 138D. No remarks, evidently very fragmentary
„ 139D. Large adult male calvaria, occipital renflement moderate, the front part of the calvaria having been broken away, a false impression of shortness is given, skull was really long in all probability
„ 140D. A large male skull, much depressed and flattened
„ 141D. A large adult male skull, with prominent brow-ridges, occipital renfle ment slight, slightly bathrocephalic, great lateral crushing, and with it (in this case) elevation vertically
„ 142D No remarks
„ 144D A long, narrow, slightly byrsoid skull, adult male, brow-ridges and occipital renflement not marked, face much damaged
„ 146D An adult male skull of moderate size, brow-ridges distinct, occipital renflement distinct, resembles usual type, but its narrowness is exaggerated through compression

TABLE VI —*Prehistoric Crania Crete (Palaikastro, Patema, Agios Nikolaos, &c)*

Measurements in mm	Male		Female	
	mm	No	mm	No
Cranial length	186 4	64	177 3	23
Cranial breadth	136 8	50	129 5	17
Breadth index	73 4	—	73 0	—
Basi-bregmatic height	130 2	20	119 3	9
Height index .	69 8	—	67 2	—
Auricular height	118 9	25	111 5	11
Circumference .	515 9	21	499 7	11
Basi-nasal length	100 0	23	94 7	6
Basi-alveolar length	95 9	11	91 7	4
Alveolar index	95 9	—	96 8	—
Facial height (upper)	65 0	13	61 7	6
Bizygomatic width	122 5	5	119 0	2
Upper facial index	53 1	—	51 8	—
Orbital height .	31 7	22	32 6	7
Orbital width	39 5	13	37 6	4
Orbital index	80 2	—	86 7	—
Nasal height .	48 9	13	48 5	4
Nasal width . .	24 2	10	24 6	4
Nasal index	49 4	—	50 7	—

Part III

A Notes on the Tibiæ from Palaikastro and its Neighbourhood

(a) Bones of Pygmy Dimensions and the Question of a Pygmy Race in Crete in the Neolithic Period

In a report published in 1903[11] I described some limb-bones from Agios Nikolaos, and drew attention to their small size I have realised lately that some of those bones are so small as to deserve a more detailed description and comparison than I gave in the publication mentioned above In particular I notice that three of the tibiæ fall far short of the length of the corresponding bone in skeletons of admittedly pygmy types, such as the Andamanese and the South African Bush race In drawing attention to this remarkable fact, I have to add that the bones from Agios Nikolaos are undoubtedly mature, and that they are shorter than the bones from Schweizersbild, upon which Professor Kollmann has based his description of a pygmy European race of neolithic antiquity

The evidence for the preceding statements is here set forth in two tables —

Table VII —*Early Cretan Bones (measurements of length in mm)*

Femora .	Patema, 367; Agios Nikolaos, 372	Mean, 369 5 (2)
Tibiæ .	Agios Nikolaos, 283, 287	„ 285 (2)
Radii	Agios Nikolaos, 211, 214	„ 212 5 (2)

Such are the dimensions actually observed It will be noted that one very short femur occurred at Patema The bones from this site (near Roussolakkos) are assigned to the Minoan Period, and are thus less ancient than those found in the Neolithic Rock-shelter at Agios Nikolaos

Turning now to the comparison of these short Cretan bones with the other types mentioned, I have to draw upon the data provided by Professor Pearson in his memoir on the reconstruction of the stature of prehistoric skeletons ('Phil Trans ' cxcii , A, p 169) Taking all the data together, we find the following list results —

Table VIII —*Mean Length of Femur, Tibia, and Radius in mm (cf fig 8)*

Bone	Early Cretan	Bush	Andamanese	Schweizersbild
	♂	♂ and ♀	♀	♂ and ♀
Femur . .	369 5 (2)	375 (6)	380 (26)	373 (3)
Tibia .	285 (2)	317 (6)	321 (26)	313 (2)
Radius .	212 5 (2)	206 (6)	210 (26)	226 (1)

The numbers in brackets are those of the observations whence the mean values are derived

The Akka dwarfs mentioned in Professor Pearson's memoir are undoubtedly smaller than any of the types in this table On the contrary, a Bambute pygmy (an adult male) provides higher figures—viz , left femur 386 (left side), tibia 309, left radius 218 These data are provided by Dr. Shrubsall [12]

[11] *Annual of the British School at Athens*

[12] *Cf. The Uganda Protectorate*, vol. ii , by Sir H. H Johnston.

Without entering into further details, I have to submit that if the neolithic skeletons of Schweizersbild are accepted as establishing the existence of a pygmy race in that locality, then these early Cretan skeletons here described possess an even better claim to be recognised as pygmies

But these short Cretan bones do not stand alone in Southern Europe I find that in 1904 Professor Giuffrida-Ruggeri described a precisely similar tibia from a neolithic site near Verona [13] This simi-

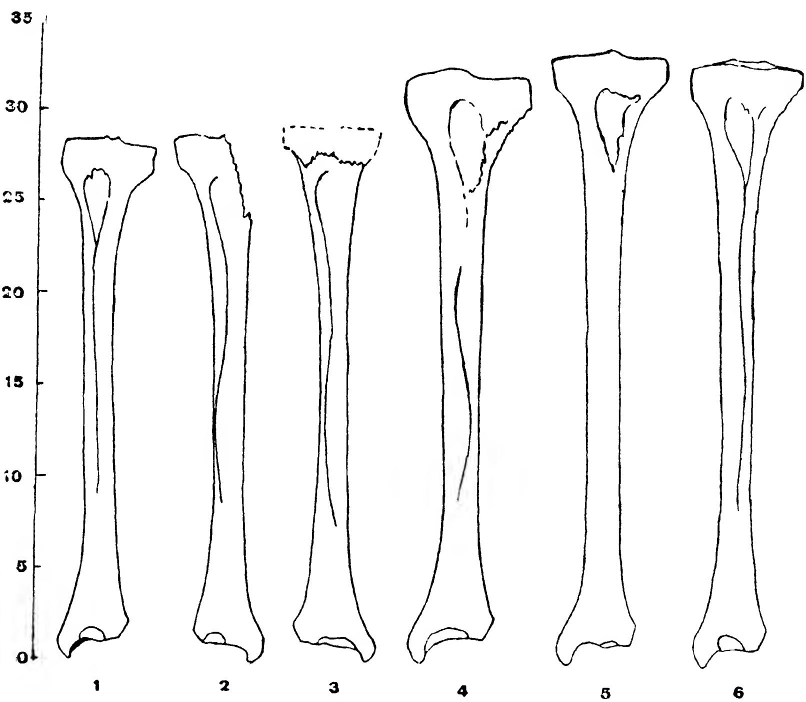


FIG 8 —Various tibiæ of pygmy size (1) (2) (3) Neolithic Cretans, Agios Nikolaos (4) Mori-ori native, Chatham Island (5) Bush native, South Africa (6) Andaman Islander From specimens in the Cambridge Museum. The scale is in centimetres

larity is established by a comparison of the dimensions of the Verona tibia with the smaller specimen from Agios Nikolaos

	(a) Crete	(b) Verona
1. Length	283 mm	280 mm.
2 Ratio of circumference of shaft to length = 100 .	22 9	22 9
3 Angle of retroversion of head on shaft . . .	11°	13°

Professor Giuffrida-Ruggeri claims that he has established the correctness of his view assigning the Verona tibia to the male sex The index quoted as (2) above is considered to provide conclusive evidence on this point The Cretan tibia has an equal claim to be

[13] *Cf L'Anthropologie*, 1904, p 37

assigned to the same sex, and the second small Cretan tibia is distinctly more massive, as may be seen from the appended tracings from a photograph (fig 8), in which the Cretan tibiæ appear as Nos 1, 2, and 3 Lest too much stress should be laid upon the characters of the tibia only, I may mention that certainly one skull at Agios Nikolaos, and several from near Palaikastro, are sufficiently small to be approximate in size to these small limb bones The occurrence of a very short thigh-bone at Patema has been mentioned already

It is tempting to proclaim at once the discovery of a pygmy race in neolithic Crete, in the case of the Schweizersbild remains the temptation was too great for Professor Kollmann to resist But some consideration is necessary, and though pygmy dimensions must be conceded to the Cretan remains here considered, I do not believe that the facts provide a basis for the conclusion that a distinct race of pygmies is thus demonstrated to have existed At present I do not know how to exclude the alternative view, viz , that the pygmy individuals are stunted representatives of their congeners The seriation of the tibial lengths is relevant in this respect, and it gives us the following list —

TABLE VIIIA.—*Tibiæ from Palaikastro and its Neighbourhood Maximum length (in mm)*

355	Palaikastro.
354.	,,
353.	,,
348	Agios Nikolaos
343.	Palaikastro
341.	,,
338.	,,
330	,,
328	Agios Nikolaos
327.	Palaikastro. (Also Schweizersbild)
322 5	,,
322	Agios Nikolaos
320	,, ,,
318.	Palaikastro.
(299	Schweizersbild)
287	Agios Nikolaos.
283	,, ,,
(280	Verona)

The distinct gap between the specimen (from Palaikastro) measuring 318 mm. and its successor may ultimately prove the genuineness and segregation of a pygmy type, but it will be noticed that one of the Schweizersbild ‘ pygmies ’ is on the upper side of that gap Taking this into consideration, and remembering that the total number of records is but nineteen, I hold that local degeneracy of growth cannot be excluded as a possible explanation I should be prepared to find the gap (mentioned above as existing between 318 mm and 299 mm) diminished by future records Indeed, upon investigation I find that Professor Pearson [14] publishes data which do reduce the gap, for he mentions a tibia of 307 mm as derived from a Romano-Gaulish interment, and he adds records of nine female ‘ row-grave ’ tibiæ, with a

[14] *Op. cit.*

mean length equal to 303 mm only That these data are for female bones must not be forgotten However, Mr. Hawes, on the other hand, has commented with emphasis[15] on the local reduction of stature manifested in the little island of Gavados (off the coast of Sphakia), in the neolithic period (and even later), similar agencies may have been at work in the neighbourhood of Palaikastro At the same time, the occurrence of these neolithic individuals with pygmy stature is worthy of very special notice, and the interpretation here preferred is not submitted as in any way final

(b) THE 'SQUATTING' FACET.

The tibiæ from Agios Nikolaos possess yet another interesting character, viz, the presence in six instances (all that were available for the observation in question) of the facet at the lower end of the bone known as the 'squatting' facet This facet is undoubtedly associated

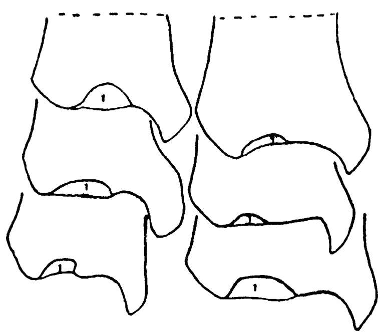


FIG 9 —The 'squatting facet' (No 1) shown in each of six tibiæ of neolithic antiquity: from a rock-shelter at Agios Nikolaos near Palaikastro (× ½)

with the habitual assumption of the attitude thus indicated, but the chief point of interest is the constancy with which the facet appears in these neolithic Cretan bones Tracings of the parts of the bones in question are appended (fig 9)

B —*The Tibiæ and Platycnemia*

A large number of fragmentary tibiæ (shin-bones) was available for the determination of the occurrence and frequency of the flattened variety described as 'platycnemic' It will be fair to consider the vast majority of the platycnemic bones as exhibiting the 'posterior tibial' variety of the conformation For in my notebooks I find but one or two specially mentioned as exhibiting the 'soleal' type of platycnemia.

(i) THE MATERIAL

One hundred and twenty-nine ancient bones were measured at Palaikastro and its neighbourhood For the purpose of comparison it was necessary to subdivide them first into two groups according to their

[15] *Brit. Assoc. Reports*, Sheffield, 1910, p. 234.

absolute dimensions. The smaller group is probably composed mainly of female bones. Each group (large bones and small bones) was then subdivided into two others (for the right and left limb respectively).

(ii) Subdivisions.

The fourfold mode of division thus adopted results as follows:

Tibiæ, 129.

	Large bones	Small bones
Right side . .	49	11
Left side	60	9
Total	109	20

(iii) The Larger Bones.

The large bones will be considered first. The means of the diameters and of the indices based upon these have been tabulated (Table IX.). I have added the determinations of the standard deviation, the coefficient of variability, and the coefficient of correlation. The following remarks are of importance in connection with these results:

Table IX.—*Cretan Tibiæ (Palaikastro, &c.).*

Character	Side to which Bones belong	No. of Examples	Mean	σ	C	$\frac{\sigma^2}{N}$	Remarks
1. Antero-posterior diameter	R.+L.	109	31·65	2·66	8·3	0·065	Only 'large' tibiæ considered
	R.	49	31·80	2·69	8·4	0·152	
	L.	60	31·52	2·63	8·21	0·115	
2. Transverse diameter	R.+L.	109	20·62	2·07	9·85	0·039	Ditto
	R.	49	20·84	1·84	8·76	0·069	
	L.	60	20·44	2·13	10·65	0·076	
							Range of Index, 50–79
3. Index	R.+L.	109	65·36	5·24	8·06	0·252	65 as mean index
	R.	49	66·03	5·10	7·72	0·528	66 as mean index
	L.	60	64·84	5·16	7·94	0·444	65 as mean index
			'r'	P.E. of 'r'			
4. Coefficient of correlation='r' for antero-posterior and transverse diameters	R.+L.	109	+0·668	±0·03			'Large' bones only
	R.	49	+0·729				
	L.	60	+0·507				

The means of the diameters are less than those for Anglo-Saxon tibiæ, the only data I have for comparison.[16] But the estimated stature of the early Cretans is but 1,625 mm., as against the estimate of 1,680 mm. provided by Mr. Parsons for the Anglo-Saxons.

The most variable dimension is shown (by the coefficient of vari-

[16] *Cf.* Parsons, *Journal of the Royal Anthropological Institute*, vol. xli., January and June 1911, pp. 126, 127.

ability) to be the transverse diameter of the *left* tibia The seriation tables for this diameter may be summarised as follows —

TABLE X.

	Transverse Diameter Right Tibia (49) Per cent	Left Tibia (60) Per cent
Above the mean value . . .	38 77	55
Of the mean value	28 57	10
Below the mean value	32 65	35

The frequencies for the *left* tibia clearly explain the greater value of the corresponding coefficient, and suggest the presence of two strongly contrasted types of bone Such asymmetry has not been recognised previously

[Pre-dynastic Egyptians present the same feature, thirty right tibiæ yield me a mean *index* of 66, against 64 for thirty left tibiæ]

The index of Platycnemia[17] next calls for consideration And it will be noticed that on the average the left bone provides a lower index (64 84) than does the right (66 03) This difference between the right and left bones may be further emphasised by the following summary of the seriation tables —

TABLE XI

Platycnemic Index

Values below 59 . .	Right Tibia	No example
	Left Tibia	Six examples = 10 %
Values above 75 . . .	Right Tibia	Two examples = 4 08 %
	Left Tibia	No example

Turning to the comparison of the prehistoric Cretan bones with those of other localities and races, I find the materials collected by Professor A Thomson and Professor Manouvrier suitable for my purpose From the data supplied by them,[18] I have drawn up the following list, introducing my Cretan and Egyptian data

TABLE XII

Type	No of Examples	Index	Type	No of Examples	Index
Europeans	31	73 7	Ancient Egyptians	3	66 7
Vedda	3	72 5	Andamanese	30	65 9
Small Cretans	20	72 13	Large Cretans	109	65 4
Peruvians .	6	70 4	*Pre-dyn Egyptian*	60	65·1
Lapps . .	7	70 2	Large Guanche	?	64 9
Negroes	12	69 7	New Caledonians	4	64 2
Eskimo . .	5	68 5	Large Crécy	25	61 9
Bush . .	5	68 2	Moderate Crécy	23	61 5
Polynesians . .	8	68 0	Moderate Guanche	?	61 3
Australians . .	22	66 8	Tasmanians .	3	60 3

The prehistoric Cretan bones are observed to fall among the prehistoric representatives of other types, and they are not far removed

[17] Platycnemia is distinct when the index is below 69, and it is very marked when the index is below 63.

[18] Thomson, *Journal of Anatomy and Physiology*, vol xxiii , 1888–89, p 638 , Manouvrier, *Mém. de la Soc. d'Anth. de Paris* (2), 3, 1888 , Klaatsch, comparing the data in the foregoing memoirs, *Anatomische Hefte*, X., 1901, S. 671.

from the early Egyptians and the Guanches It is to be remarked, further, that the large Cretan bones are more platycnemic than the small ones Herein they follow a general rule first recognised by Manouvrier

The coefficient of correlation (*cf* Table IX 4) is rather high in comparison with its value for most *cranial* characters I have no comparable data, so I will merely point out the fact that the correlation of the two diameters is least in the left bones, and this is easily intelligible in the light of the remarks already made in commenting upon their variability as compared with those of the right leg

(iv) THE SMALLER BONES.

The small tibiæ remain for consideration The data are as follows:—

TABLE XIII.

—	No	Index (mean value)	Antero-posterior Diameter (mean value) in mm	Transverse Diameter (mean value) in mm
Right . .	11	72 88	25 23	20 2
Left . .	9	71 23	24 88	17 72
Right and Left .	20	72 13	25 07	19 08

The outstanding feature is the greater tendency of the *left* tibia to assume platycnemic proportions This has been the subject of comment already The indices show less platycnemia than in the case of the large bones Apart from these remarks, no further discussion of these records is necessary here

C *The Femora from Palaikastro and its Neighbourhood.*

(i) THE MATERIAL.

As in the case of the tibia, the frequency and degree of occurrence of various types of femoral conformation could be determined in fragments useless for estimates of stature As with the tibiæ also, a subdivision into large and small groups, and again into those of the right and left limbs respectively, has been carried out in respect of the femora One hundred and twenty-four specimens are available

(ii) SUBDIVISIONS.

The grouping is therefore as follows:—

	Large femora	Small femora
Right .	52	8
Left .	52	12
Total .	104	20

(iii) THE LARGER BONES.

The large bones will be considered first The observations were those necessary for determining the index of Platymeria This character,[19] a flattening of the femoral shaft, is very erratic in its distribution, even more so than is platycnemia Like platycnemia, it is locally (*e g*, in Western Europe) very characteristic of prehistoric

[19] The recent literature of Platymeria has been summarised admirably by Professor Klaatsch in the *Anatomische Hefte*, Band X.

skeletons of particular periods, such as the Neolithic Period in the area just mentioned. As regards the index, it will suffice to state that when this falls below eighty, the character in question becomes very distinct As in the case of the observations on the tibia, I have determined the mean values of the two diameters, and of the index derived from these As before, so here I have added the values of the standard deviation, the coefficients of variability and of correlation in each case These data are set forth in the following table —

TABLE XIV.—*Cretan femora* (*Palaikastro, &c*)

Character	Side to which Bones belong	No of Examples	Mean	σ	C	$\frac{\sigma^2}{N}$	Remarks
1. Antero-posterior diameter	R + L	104	22 96	2 35	10 21	0 051	Only 'large' femora are considered
	R.	52	22 77	2 17	9 43	0 091	
	L	52	23 16	2 30	10 00	0 101	
2 Transverse diameter	R + L	104	30 73	2 51	8 1	0 060	Ditto
	R.	52	30 41	2 41	8 03	0 112	
	L	52	31 00	2 57	8 29	0 127	
3 Index .	R + L	104	74 9	6 38	8 51	0 382	Range 61–94
	R	52	75 0	6 61	8 81	0 839	
	L.	52	74 8	6 15	8 20	0 728	
			'r'	P E of 'r'			
4. Coefficient of correlation of antero-posterior and transverse diameters = 'r'	R + L	104	+0 508	± 044			'Large' bones only
	R	52	+0 568				
	L	52	+0 572				

Taking the mean values of the diameters, it will be noticed that they fall below those of the Anglo-Saxon femora recorded by Parsons,[20] and far below those of modern British femora With regard to variability, the high coefficient (10 00) provided by the *left* femora for the antero-posterior diameter is especially noteworthy The difference between the right and left sides is not so great as in the tibiæ, but it is again the *left* side that yields the indication of greater variability Examining the seriations as in the case of the tibiæ, and again summarising the results, we have —

TABLE XV

Antero-posterior Diameter	Prehistoric Femora Right	Cretan Femora Left
	Per cent	Per cent
Above the mean value . . .	32 55	40 4
Of the mean value . . .	23 10	17 30
Below the mean value . .	44 35	42 30

[20] *Op. cit.*, p. 125.

To appreciate the difference between the two sides the numbers falling on the mean value are to be compared. The difference is thus seen to be of the same kind as has been noted already in regard to the tibiæ.

Coming to the index of platymeria (Table XIV, 3), it will be observed that the index for the *left* femora is less than that for the right The difference is again less marked than in the tibiæ, but it is of the same kind The frequency of distribution is as follows:—

TABLE XVI.—*Index of Platymeria, Prehistoric Cretan Femora.*

——	Right Femur	Left Femur
	Per cent	Per cent
Index above the mean value	40 3	38 45
Of the mean value (75) . .	11 5	5 75
Below the mean value (and therefore markedly platymeric) . .	48 2	55 8

The mean value of the index of platymeria (for the large bones of both sides combined) associates the prehistoric Cretans with the Guanches and the Ancient Egyptians This indication confirms that given by the index of platycnemia I have made out the following list from data recorded by Professors Hepburn and Lehmann-Nitsche and summarised by Professor Klaatsch [21]

TABLE XVII.

Type	Mean Value of Index	Type	Mean Value of Index
Eskimo .	88 3	Alemans	79 7
Modern French	88 0	Chinese .	79 7
Creoles .	86 6	Andamanese	78 0
Bush . .	86 2	Kaffirs .	77 6
Negroes . .	85 3	Venezuelans	76 1
Neanderthal (R)	85 3 (R)	Japanese	75 1
Australians	82 2	Large Cretans	74 9
Oceanic Negroes	82 0	Spy No. II	74 3
British . .	81 8	Ancient Egyptians	71 0
Small Cretans .	81 55	Guanches .	70 7
Manitoba Indians	80 8	Fuegians	66 9
Neanderthal (L)	80 5 (L)	Polynesians .	65 4
Spy No I. (R)	80 0 (R)	Maoris	63 6

Lastly, the relation of the smaller to the larger Cretan bones is the same as in the case of the index of platycnemia.

The coefficient of correlation (Table XIV, 4) is not so high as that for the two diameters of the tibia, though it is not to be described as small in comparison with the values of this coefficient in the case of most cranial dimensions But I have no comparative data for femora, so that I must be content to provide the record for the Cretan series without further comment.

[21] *Anatomische Hefte*, 1901, Band X., S. 629.

(iv) The Smaller Bones.

Twenty of the smallest femora have been set aside, and yield the following mean values.—

	Number	Mean Value of Index	Mean Value of Antero-posterior Diameter	Mean Value of Transverse Diameter
Right .	8	82 43	22 62	25 93
Left. .	12	80 97	21 12	26 12

As with the larger bones, so here the *left* femora are more platymeric than the right And the small series is less platymeric than the large one The factors (*a*) of sex (*b*) of absolute dimensions enter into this matter, as in the comparable instance of platycnemia

D *General Outcome of the Data considered in Sections B and C, supra*

A general review of the data discussed in sections B and C leads to the conclusion that the prehistoric inhabitants of Sitia resemble other early Mediterranean representatives of that type in respect of their tibiæ and femora, as well as in their cranial conformation Otherwise the prehistoric Cretan bones follow a general rule whereby the longer bones (including a majority of males) differ from the smaller and shorter ones (including a majority of females) In both the tibia and femur alike the right and left limbs are seen to differ in a manner which has not been previously recorded and which has yet to find an explanation Other data are provided, for which no comparable materials are yet on record

E *Other Observations on the Limb-bones of the Ancient Inhabitants of Palaikastro and its neighbourhood*

The frequency of the perforation of the humerus (in the ' olecranon fossa ' at its lower end) has been recorded in numerous instances The excavations in Eastern Crete during 1903 provided 68 bones on which observations could be made In regard to the perforation mentioned above, the following data were collected —

		Per cent
No of humeri examined (the sex was not determined)	68	100
No of perforate bones	17	25
No of imperforate bones . . .	51	75
	68	100

The frequency of perforation is greatly in excess of that in modern European skeletons I have the following records for comparison —

Table XVIII.

	Per cent
Western Europeans (modern)	4 to 5
African negroes	21 7
Polynesians	34 3
' Altaic ' and American races .	36 2
Prehistoric	
Guanches of the Canary Islands	25 6
Pre-dynastic Egyptians	60 0

The similarity of the records from Crete to those from the Canary Islands is remarkable

PART IV —*The Physical Characteristics of Modern Greeks*

This report is an extension of section (*d*) of my Report to the Cretan Committee in 1903 The material there described consists of measurements made on 100 individuals in the Reformatory at Athens Of these individuals, one was a Cretan this necessitates his exclusion here In another instance, the measurements are not complete as to number In consequence the available data are derived from 99, or in some cases 98 individuals

In 1903 a very brief abstract of the results was submitted On the present occasion I amplify the earlier notes by the results summarised in the two tables appended

A *Comparative Lists of Physical Characteristics of Greek Reformatory Youths and Modern Cretans*

A These tables give results expressed as percentages the observations are tabulated with the corresponding data for adult Cretans The latter are much more numerous than the Greeks they were measured by myself in 1903, but were not included in my report of that year I ought to mention in this place that as regards Crete, and perhaps as regards Greece also, Mr Hawes must possess material incomparably greater than mine But even though the publication of those more extensive investigations may lead to modifications of my results, I take the view that, since they are not yet published, I ought to report without further delay to the Committee on the task committed to me.

TABLE XIX —*Greek Reformatory Youths General Physical Characters compared with those of adult Cretans*

—	Locality: Greece	Locality: Crete	—	Locality: Greece	Locality: Crete
	Number 96	173		Number 96	173
Complexion	Per cent	Per cent	*Eyes* Colour	Per cent	Per cent
Pale	44 2	10 5	Brown, Light	2 8	1 7
Ruddy	35 8	60 5	„ Medium	5 2	8 25
Dark	16 82	29 0	„ Dark	38 5	12 60
Freckled .	3 18	0	*Face*		
Hair Colour			Narrow .	42 42	31 3
Red . . .	1 04	0 56	Medium . .	33 33	45 0
Fair . .	3 15	3 40	Broad .	24 24	23 7
Brown . .	27 125	13 30	*Ears*		
Dark . .	22 825	36 00	Flat	54 1	74
Jet-black. . .	45 75	47 10	Outstanding . .	45 9	26
Eyes. Colour			*Lobes of Ears*		
Blue. . . .	2 6	8 5	Present . . .	72 54	69 5
Grey . . .	13 0	12 6	Absent . . .	27 46	30 5
Green . . .	2 6	15 9	*Cheek-bones*		
Hazel . . .	35 0	40 5	Inconspicuous .	71 1	50 2
			Prominent . .	28 9	49 8

Table XIX —This table requires the following comments —

With regard to complexion, the only point worth notice is the presence of freckled individuals in Greece and the absence of any record of their occurrence in Crete For the rest the circumstances of existence in the Reformatory must be held largely accountable, so far as any contrasts appear

The hair offers few contrasts in point of colour, save that the occurrence of red hair seems rather more pronounced on the mainland

The eye-colour is distinctly darker among the Greek youths The proportions of the face are not very different in the two areas Such differences as the table suggests are negligible in view of the lesser age of the Greeks Similar remarks apply to the characters of the cheek-bones On the whole, then, the colour of the eyes offers the only reliable basis for argument as to differences between the Cretans and the population of the mainland and the nearest islands

TABLE XX —*Greek Reformatory Youths, Head Dimensions compared with those of Adult Cretans*

—	Locality		—	Locality	
	Greece	Crete		Greece	Crete
1 Number	98 or 99	200	Mesaticephalic %	25 51	45
2 Head length	183 6	186 27	Brachycephalic %	71 43	42 5
3 Head breadth	151 1	148 33	10 Standard deviation of cephalic index	4 18	4 10†
4 Cephalic index .	82 5	79 6			
5. Head height .	136 8	136 8			
6. Height index .	74 7	73 5*	Probable error	±0 201	±0 048
7. Nasal height	52 9	54 2	11 Coefficient of variation of cephalic index	5 09	5 17†
8 Nasal width	34 6	33 7			
9 Nasal index	65 7	62 2*			
Cephalic Index			Probable error	±0 246	±0·061
Dolichocephalic %	3 06	12	12 Age in years	19 1	Adult

* From mean values † Data by Mr. Hawes from 1,600 adult males

B Mean Values, Standard Deviation, and Coefficients

Table XX shows that the Greek youths have a greater frequency of brachycephaly than the Cretans The latter are, however, from all parts of Crete If the several provinces of Crete be compared with each other and with these Greek records, certain regions of Crete will show a frequency of brachycephaly surpassing that met with among these Greeks Further discussion of this matter is reserved for the section dealing with the distribution of the various values of the cephalic index.

The relative value of the vertical diameter of the head shows that the latter is more nearly spherical in the Greek youths

I ascribe the difference in the nasal index to the difference in age of the two series, at least, I am sure the factor of age is responsible for most of the difference observed

The standard deviation is represented by a figure which is large in comparison with many of those now on record I have worked out a number of comparable data, which will be found in a paper on

Sardinian craniology [22] I must observe that the youth of the Greeks is no doubt partly responsible for the very high numerical values assigned to the standard deviation and the coefficient of variation This factor is negligible in the case of the Cretans, who must be regarded therefore as the more variable, even though the actual figures do not indicate this But both are to be regarded as very variable or as presenting the characters of a mixed stock of humanity Apart from this, and taking the figures as they stand, the standard deviations provide a means of testing the value observed to obtain between the figures recorded for the cephalic index in the two series Those values are respectively 82 5 (Greeks) and 79 6 (Cretans), or 79 2 if we take Mr Hawes' mean value for 1,600 Cretans The latter figure (79 2) is used since the standard deviation (4 1) is based upon it The test is to compare the expression $M_1 - M_2$ (in this case 82 5 – 79·2, or 3 3) with

$$0\ 6745 \sqrt{\frac{\sigma_1^2}{N_1}+\frac{\sigma_2^2}{N_2}}=0\ 6745 \times 0{\cdot}434=0\ 293.$$

That is, we have to compare 3 3 with 0 293 The former is more than thrice the amount of the latter, and on this account the difference between the Greeks and Cretans here observed is not accountable to 'random sampling,' but to some real difference independent of the actual numbers of individuals measured

TABLE XXI —*Greek Reformatory Youths*

Character	No	Mean	P E of Mean	σ	P E of σ	C	P E of C	$\frac{\sigma^2}{N}$
			±		±		±	
Cephalic index	98	82 5	0 285	4 18	0 201	5 09	0 246	0 178
Head length	99	183 6	0 430	6 35	0 305	3 45	0 165	0 408
Head breadth	98	151 1	0 422	6 20	0 299	4 10	0 197	0 392
Head height	99	136 8	0 388	5 735	0 274	4 18	0 201	0 332
Height index	99	74 7	0 261	3 85	0 183	5 13	0 246	0 150
Nasal height	99	51 9	0 245	3 62	0 173	6 96	0 334	0·132
Nasal width	99	34 6	0 152	2 236	0 107	6 58	0 316	0 051
Nasal index	99	65 7	0 421	6 21	0 298	9 41	0 450	0 390

TABLE XXII —*Correlations.*

Characters	No	'r'	P E of 'r'
			±
Length : Breadth .	98	+0 086	0 0667
Length : Height .	99	+0 1001	0 0667
Breadth : Height .	98	+0 255	0 0634
Cephalic index : Length	98	–0 630	0 0340
Cephalic index : Breadth	98	+0 746	0 0242
Cephalic index . Nasal index	98	+0 0573	0 0678
Nasal height : Nasal width	99	–0 0133	0 0677

[22] Published in the *Zeitschrift für Morphologie und Anthropologie,* Band xiii., 1911.

I have supplied the data necessary for extending tests of this kind in the next table (XXI) where the standard deviation, the coefficient of variation, and the numerical value of the ratio $\frac{\sigma^2}{N}$ are recorded for each of the measurements made on the Reformatory youths

Table XXII—The correlation of the length with the breadth of the head is extremely low The comparable data for the height and length, as for the breadth and height, are in an ascending scale, so that the sequence runs as follows —

1 Length and breadth (least closely related)
2 Length and height
3 Breadth and height (most closely related)

But the correlation is of a low value throughout The value of the coefficient for the cephalic index and the length is more interesting As the table shows, this is of high value, but with the negative sign (−0 63) That this should be the case could be inferred from what I have stated in regard to the correlation of the length and breadth It is, however, of interest to compare this value with those derived from three sets of skulls presenting marked dolichocephalic proportions Thus we have

		Index
Greek heads . .	−0 630	(80 5)
Sardinian crania	−0 543	(71 53)
Naqada Egyptians	−0 551	(72 99)
Mediæval English	−0 547	(74 34)

Correlation here seems to be comparatively independent of the absolute value of the cephalic index

C *Distribution of the Cephalic Index and the Nasal Index, as shown on the Maps*

The regional distribution of the young Greeks is now to be considered Their great variability in respect of the cephalic index has been noticed already Hitherto I have dealt with them as a single group, but it is necessary to add that they come from a wide area, and that, of the ninety-nine, fourteen are from islands close to the mainland, while the remote islands supply four individuals They are classified as follows —

I . . .		Mainland . .	81
II Islands close to mainland :	{	Ionian Islands .	8
		Eubœa . .	4
		Spetzai . .	2
III Remote islands . .		Amorgos, Mitylene, Naxos, Paros, one each . .	4
			99

With regard to the cephalic index, I have drawn up the comparisons set forth in Table XXIII.

TABLE XXIII.

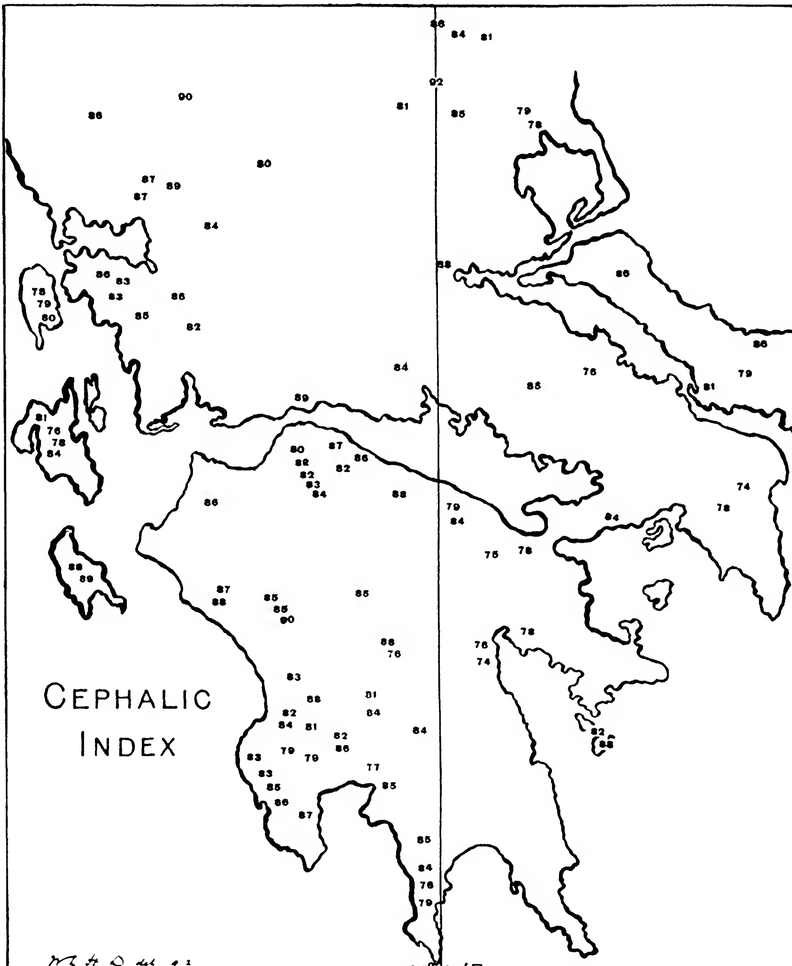
1. Range of the cephalic index (in units):—	
(a) for 98 individuals from all parts . . .	74 to 92
(b) for 18 islanders (Ionian islands, &c.) .	75.4 to 88.1
(c) for 8 Ionian islanders	75.4 to 88.1
(d) for 4 islanders of Eubœa .	78.1 to 86.0
2. Mean value of the cephalic index:—	
(a) for 98 individuals from all parts . .	82.5
(b) for 18 islanders (Ionian islands, &c.) .	81.75
(c) for 4 islanders of Eubœa . .	82.5
(d) for 8 Ionian islanders . .	81.4
(e) for 2 islanders of Spetzai . .	84.4
(f) for 4 islanders (Amorgos, &c.) .	80.4

On this Table XXIII. I have to remark first that the range of variation in the Ionian islands is very striking. As regards the mean value of the cephalic index, the similarity between the figures for the mainland and those for Eubœa are noteworthy. In a previous section of this report (Part I., p. 4) I suggested that the investigation of Eubœa would be instructive, particularly were a search instituted for the type of head described as 'armenoid.' When I made that recommendation I had not undertaken the analysis given in Table XXIII. But that analysis provides some confirmation (slight, it is true) of the validity of my suggestion. Thus two of the four records from Eubœa (Nos. 169 and 170) have indices above 85, *i.e.*, are markedly brachycephalic, and the heads are moreover short rather than broad (the lengths being respectively 179 and 181). In each instance the age of twenty-one years had been attained, so that the full dimensions of the cranium had been nearly acquired. In the absence of any head-contours I am unable to press this claim further.

Returning to other points in Table XXIII., the high degree of brachycephaly in the island of Spetzai is worth notice. There are but two records. They may serve to show the difficulty of basing any argument on such a small number of observations. The mean value of the index is 84.4. It is claimed that Spetzai is the site of an Albanian colony. This might seem to explain the high mean value just recorded, and no doubt it actually does so. But the mean index (84·4) is derived from the indices 81.7 and 87.1. The latter should provide (according to Mr. Hawes' view) measurements indicative of a head of no great length, but very broad. Actually the measurements whence the index in question (87.1) is derived were, for length 178 mm. and for breadth 155 mm. The individual presents us, therefore, with the length characteristic of the armenoid head, combined with the breadth deemed indicative of the dorian (illyrian) type. If the age of the man be inquired into, the anomalous condition is cleared up to a large extent, for the age was but sixteen years. The head in question has (I hope) grown by now to its full size. If we allow 5 mm. in addition to the length (for the fully formed frontal sinuses), and 2 mm. be added to the breadth, the resulting values are for length 183 and for breadth 157 (the index becoming 85.7), which brings the head close to Mr. Hawes' estimate for Albanians.[23]

[23] *Cf.* Hawes' *Annual of the British School at Athens*, No. XVI., p. 267.

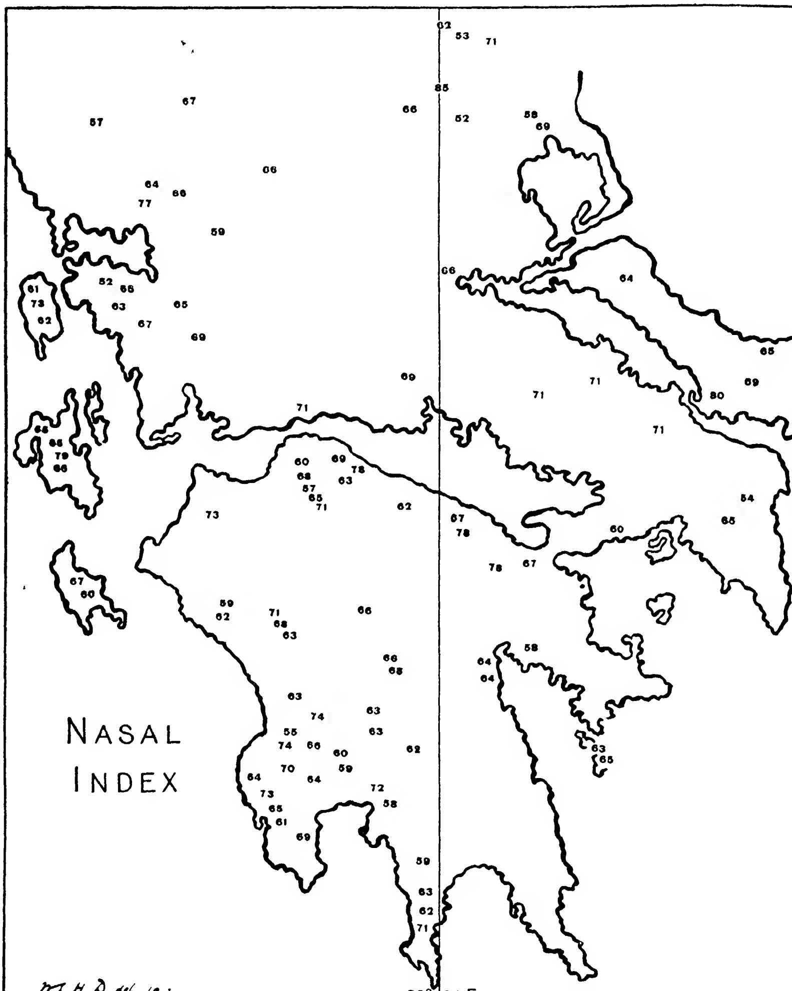
The other youth from Spetzai was eighteen years of age The head measured 178 mm by 147 mm I think that the additions in this case could not exceed 4 mm for length or 3 mm for breadth This would give 182 mm for length, 150 mm for breadth; in other words, the values would be characteristic of the armenoid head-form.



MAP I.

In continuing the attempt to extract some evidence from the distribution of the Greek youths, I prepared two maps In one of these the cephalic index (the nearest whole number is plotted) is shown The other map gives the distribution of the nasal index Taking first the cephalic index (Map I), and selecting the higher values, viz., those

of 84 or more, for purposes of comparison, I endeavoured to ascertain whether any regularity could be detected in the distribution of the shorter heads (taking those measuring 182 mm or less), and of the broader heads (155 or more) Assuming that all three brachycephalic



MAP II.

heads are of the plano-occipital type of Toldt, the shorter ones may be termed 'armenoid' and the longer ones 'dorian' It is to be noted that the seriations both of length and of breadth give indications of two peaks, one above, the other below, the mean value But I find the two groups inextricably confused, indeed, the sole conclusion I can

draw from this map of the cephalic index is that there seems to be a rather greater and more frequent brachycephaly on the western side than on the eastern Nor have my attempts to interpret the distribution of the nasal index (Map II) met with any greater success Moreover, the factor of age is almost certainly more productive of fallacy in the case of this index than in that of the cephalic index But the chief defect is lack of records

In concluding this report, I may be allowed to repeat that my first aim has been to provide a formal record of work accomplished Beyond this, I have entered into discussions so far only as they were necessary to indicate the nature of the records and the objects with which they were collected I hope that the data may be of some use in conjunction with the great stores which Mr Hawes has accumulated The measurements and the chief indices of the Greek Reformatory youths will be found in Table XXIV , which is appended

TABLE XXIV —*Greek Youths, Reformatory, Athens*

Note —The indications heading the several columns are to be interpreted as follows —

H L. = Head length.	H I = Height index
H B = Head breadth	N L. = Nasal length
H H. = Head height (auricular)	N W. = Nasal width
B I. = Cephalic index	N I = Nasal index

No	Age	H L	H B	H H	B I	H I	N L	N W	N I
4	18	189	153	142 5	81 0	75 4	52 5	34 5	65 7
6	18	180	156	148 5	86 7	82 5	55	35	63 6
7	19	190	143	130	75 3	68 4	55 5	34	61 2
8	15	183	148	133	80 9	72 7	45	36	80 0
10	16	187	159	148	85 0	79 1	56	33	58 9
11	22	192	144	131	75 0	68 2	48	37 5	78 1
14	25	189	157	127	83 1	67 2	51	35	68 6
18	19	185	143	130	77 3	70 3	54 5	36 5	66 9
19	16	179	150	129	83 8	72 1	49	38	77 6
20	17	190	149	133	78 4	70 0	52	34	65 4
	185	1864	1502	1352 0	806 5	725 9	518 5	353 5	686 0
23	18	181	152	137	84 0	75 7	54	34	63 0
24	18	185	159	146	85 9	78 9	56	34	60 7
26	25	182	154	135 5	84 6	74 4	53	35	66 0
30	16	179	148	135	82 7	75 5	55	34 5	62 7
32	19	184	161	140	87 5	76 1	55	37	67 3
33	20	181	155	139	85 6	76 8	62	32 5	52 4
37	16	170	155	137	91 2	80 6	47	35	74 5
38	18	187	147	129	78 6	69 0	50	35	70 0
40	14	172	140	137	81 4	79 7	49	34	69 4
41	19	187	?	131	?	70 1	48	34	70 8
	183	1808	1371	1366 5	761 5	756 8	529	345 0	656 8

TABLE XXIV —*Greek Youths, Reformatory, Athens*—continued

No	Age	H L	H B	H H	B I	H I	N L	N W	N I
43	20	189	157	136	83 1	72 0	51 5	38	73 7
44	18	180	136	134	75 6	74 4	48	34	70 8
46	17	182	146	139	80 2	76 4	56	35	62 5
48	18	197	154	132	78 2	67 0	54 5	38 5	70 6
51	20	186	145	126	78 0	67 7	53	34 5	65 0
52	18	182	137	144	75 3	79 1	53	34	64 2
53	20	183	152	133	83 1	72 7	50	33	66 0
56	18	180	148	138	82 2	76 7	58	36 5	62 9
58	21	195	151	131	77 4	67 2	57	33	57 9
59	19	171	152	138	88 9	80 7	55	36 5	66 3
	189	1845	1478	1351	802 0	733 9	536 0	353 0	659 9
62	18	182	146	136	80 2	74 7	50	35 5	71 0
63	18	194	147	143	75 8	73 7	53	36	67 9
64	22	185	145	129	78 4	69 7	52	35	67 3
65	18	187	157	142	84 0	75 9	59	31	52 7
67	18	191	170	141	89 0	73 8	46	32 5	70 6
68	20	177	155	128 5	87 6	72 6	52	32	61 5
72	21	187	159	132	85 0	70 6	60	31	51 7*
73	18	182	157	140	86 3	76 9	53 5	35 5	66 3
74	16	185	143	140	77 3	75 7	46	36 5	79 3
76	20	183	143	141	78 1	77 0	50	35	70 0
	189	1853	1522	1372 5	821 7	740 6	521 5	340 0	658 3
77	21	188	150	132	79 8	70 2	56	33 5	59 8
79	18	188	158	140	84 0	74 5	55	34	61 8
81	19	185	156	130	84 3	70 3	53	37·5	70 7
88	21	180	161	132 5	89 4	75 0	52	35	67 3
90	21	191	140	142 5	73 3	76 0	58	37	63 8
93	12	173	148	138	85 5	79 8	51	30	58 8
96	20	172	148	133	86 0	77 3	58	33	56 9
97	17	182	148	134	81 3	73 6	46	31 5	68 4
98	17	190	156	141	82 1	74 2	55	36 5	66 3
100	24	201 5	152	142	75 4	70 4	54	35	64 8†
	190	1850 5	1517	1365 0	821 1	741 3	538	343 0	638 6
101	19	182	158	142 5	86 8	79 5	47	36	76 6
102	20	186	156	140	83 9	75 3	52	37	71 2
103	16	179	152	139 5	84 9	77 6	50	34	68 0
104	19	174	144	128	82 8	73 6	52	34	65 4
110	19	193	147	141	76 2	73 1	49	33	67 3
111	17	180	148	139	82 2	77 2	50	32	64 0
115	20	177	144	131 5	81 4	74 0	55	30	54 5
116	17	174	148	125	85 1	71 8	55	34	61 8
117	18	188	142	136	75 5	72 3	54	33 5	62 0
121	18	197	150	137	76 1	69 5	53	38	71 7
	183	1830	1489	1359 5	814 9	743 9	517	341 5	662 5

* A Film 10. † Rhomboid.

TABLE XXIV —*Greek Youths, Reformatory, Athens*—continued

No	Age	H L	H B	H H	B I	H I	N L	N W	N I
123	19	188	144	138 5	76 6	73 6	58 5	34	58 1
124	19	174	145	132	83 3	75 9	56	33	58 9
127	19	188	146	137	77 7	72 9	51 5	35 5	68 9
131	22	184 5	157	134	85 0	72 7	59	34	57 6
132	18	188	152	130	80 9	69 1	53	33	62 3
138	22	185	162	137	87 6	74 1	56	37	66 1*
139	24	187	151	135	80 7	72 2	52	34	65 4
140	18	186	147	136	79 0	73 1	60	35	58 3
141	18	187	151	136	80 7	72 7	56	37	66 1
	179	1667 5	1355	1215 5	731 5	656 3	502 0	312 5	561 7
143	20	176	155	135	88 1	76 7	55 5	33 5	60 3
145	23	176	148	144	84 1	81 8	53	37 5	70 7
146	23	180	158	135	87 8	75 0	53 5	33	61 6
147	19	180	165	145 5	91 7	80 8	53	45	84 9
148	20	190	140	133 5	73 7	70 2	55	29 5	53 6
149	16	170	147	133	86 5	78 2	48	33	68 8
150	21	186	151	151	81 2	81 2	56	32	57 1
153	22	190	160	142 5	84 2	75 0	54	35	64 8
157	18	182 5	148	147	81 1	80 5	53	32	60 4
159	17	185	156	145	84 3	78 4	51	33	64 7
	199	1815 5	1528	1411 5	842 7	777 8	532 0	343 5	646 9
160	18	174	152	127	87 4	73 8	41 5	33	74 1
161	18	176	148	134	84 1	76 1	51	34	66 7
162	22	183	151	130 5	82 5	71 3	50	36 5	73 0
166	16	182	159	138 5	87 4	76 1	47	36 5	77 6
167	16	178	155	135	87 1	75 8	54	35	64 8
169	21	179	154	141	86 0	78 8	53	34 5	65 0
170	21	181	154	143	85 1	79 0	56	36	64 3
172	18	181	157	142	86 7	78 5	55	38	69 1
173	18	188	147	134	78 2	71 3	48	35	72 9
174	22	180	150	137	83 3	76 1	52	30 5	58 6
	190	1802	1527	1362·0	847 8	756 8	510 5	349 0	686 1
177	22	183	150	148	82	80 9	51	32	62 7
178	24	193	163 5	146	84 7	75 6	56	37	66 1
179	19	182	156	140	85 7	76 9	45	33	73 3
180	18	192	151	146	78 6	76 0	56	36	64 3
184	20	192	150	131	78 1	68 2	52	36	69 2
188	23	175	152	131	86 9	74 9	56 5	33	58 4
189	19	174	155	145 5	89 1	83 6	56	35	62 5
193	18	180	147	135	81 7	75 0	56	35	62 5
194	19	179	149	131	83 2	73 2	52	35	67 3
197	19	186	148	134	79 6	72 0	53	32	66 4
	201	1836	1521 5	1387 5	829 6	756 3	533 5	344	652 7
Epirote†	9	163	153	?	93 9	?	?	?	?
136 (Cretan)	17	179	158	136	86 1	75 9	47	33	70 21

* Bathrocephalic. † Measured in Crete.

Totals for Averages

Section	No	H L	H B	H H	B I	H I	N L	N W	N I	Age
I	10	1864	1502	1352	806 5	725 9	518 5	353 5	686 0	185
II	10(9)	1808	1371	1366 5	761 5	756 8	529	345	656 8	183
III	10	1845	1478	1351	802 0	733 9	536	353	659 9	189
IV	10	1853	1522	1372 5	821 7	740 6	521 5	340	658 3	189
V	10	1850 5	1517	1365	821 1	741 3	538	343	638 6	190
VI	10	1830	1489	1359 5	814 9	743 9	517	341 5	662 5	183
VII	9	1667 5	1355	1215 5	731 5	656 3	502	312 5	561 7	179(9)
VIII	10	1815 5	1528	1411 5	842 7	777 8	532	343 5	646 9	199
IX	10	1802	1527	1362	847 8	756 8	510 5	349	686 1	190
X	10	1836	1521 5	1387 5	829 6	756 3	533 5	344	652 7	201
	99(98)	18171 5	14810 5	13543 0	8079 3	7389 6	5238 0	3425 0	6509·5	1888
		183 6	151 1	136 8	82 5	74 7	52 9	34 6	65 7	19 1 years
Mean of		(99)	(98)	(99)	(98)	(99)	(99)	(99)	(99)	(99)

Physical Characters of the Ancient Egyptians.—Interim Report of the Committee, consisting of Professor G. ELLIOT SMITH (*Chairman*), Dr F C SHRUBSALL (*Secretary*), Professor A KEITH, *and* Dr C G SELIGMANN (*Drawn up by the Chairman*)

THIS Committee was appointed primarily with the object of acquiring, studying, and, if feasible, transporting to England a valuable and unique series of skeletons of Ancient Egyptians, buried in *mastabas* of the Second and Third Dynasties at Sakkara, which Sir Gaston Maspero, Director-General of the Egyptian Government Antiquities Department, had placed at the disposal of the Chairman of this Committee The material was brought to light in the course of the excavations carried on for the Antiquities Department by its Senior Inspector, Mr J E Quibell, who did everything in his power to facilitate and help in the Committee's investigations The cemetery in which the material was obtained is situated a short distance to the north of the Pyramids of Sakkara, and included the tomb of Hesy, from which the famous wooden panels, carved in relief (now in the Cairo Museum), were obtained by Mariette Pasha many years ago The tombs themselves are of very great interest, and will be described in detail in Mr Quibell's official reports, as well as in his demonstration at the Dundee meeting They are the earliest known examples of elaborate subterranean rock-cut tombs, and range in date from the latter part of the Second Dynasty until well into the period of the Third Dynasty.

The crucial importance of the human remains buried in these tombs depends upon the fact that the earliest bodies hitherto found in Lower Egypt (exclusive of those brought to light at Turah in the winter of

1909-1910 by Professor Hermann Junker, and described by Dr Derry,[1] to which reference will be made later) belonged to a later period, Fourth to Sixth Dynasties, and revealed undoubted evidence of considerable alien admixture, such as does not occur, except in rare sporadic instances, in the earlier remains from Upper Egypt The problem for solution was the determination of when and how this process of racial admixture began.

The contemporary and earlier material found by Professor Junker upon the opposite (east) bank of the river and a little further north was in a very bad state of preservation, and no adequate photographic record was obtained to permit of exact comparisons with other collections But Dr Derry's report, which seems to suggest that the alien element, in these poorer graves, did not become certainly appreciable until the time of the Third Dynasty, served to add to the interest of Mr Quibell's material and to make it more than ever desirable to secure and preserve a collection of such crucial importance for the investigation of the problems of Egypt's anthropological history

The chief difficulty that faced the Committee was how satisfactorily to deal with a collection of most fragile bones, a large proportion of which were certain to become damaged more or less severely during transport As there was no anthropologist on the spot to measure and make descriptive notes on the material, it was proposed to employ experts to photograph each skull and other important bone before they were treated with size or other strengthening agent in preparation for transport to England.

But while preparations were being made for carrying out this scheme, most of the difficulties were removed by the fact that the Egyptian Government requested the Chairman of this Committee to go out to Egypt in connection with the work of the Archæological Survey of Nubia, and it thus became possible for him to visit Mr Quibell's excavations in person, to examine and measure all the material on the spot, to supervise the work of photographing and packing it for transmission to England It was possible to do so much in the short time at his disposal, because Mr Quibell and his trained workmen afforded every help, and Mr Cecil M Firth and his native photographic assistant, Mahmud Shaduf, of the Nubian Survey, volunteered to help Mr Firth took about a hundred and thirty photographs of the material Every help was also given by the Egyptian Survey Department in the loan of instruments and other apparatus Furthermore, the authorities at the Museum of the Royal College of Surgeons in London offered to take charge of and repair the material on its arrival, and to grant the Committee every facility for its investigations They have borne all costs of transport

Full notes and photographs were obtained of all the human material rescued by Mr Quibell, consisting of the remains of thirty-nine individuals of the Second and Third Dynasties, most of which is now safely housed in the Royal College of Surgeons' Museum It will take some time to complete the investigation of this material for the purposes of a final report, but it may be stated that the material closely resembles

[1] *Denkschr d k Akad d Wissensch in Wien*, 1912.

the human remains of the Pyramid Age found in neighbouring sites of a somewhat later date. There are quite definite evidences of some racial influence alien to the Proto-Egyptian race; but the difficult problem is raised as to how much of the contrast in the features of the two populations—Upper Egyptian and Lower Egyptian at the Second and Third Dynastic Period—are due to admixture and blending, and how much, if any, is due to the specialisation in type of the Delta portion of the Proto-Egyptian people

The investigation also revealed some suggestion of attempts at mummification as early as the Second Dynasty—a fact of some interest, as the earliest undoubted case of mummification is referred to the Fourth or Fifth Dynasty (more probably the latter); and no evidence has ever been obtained before of attempted mummification of a body which was not buried in the fully extended position

While in Egypt the Chairman took the opportunity of comparing the Sakkara skulls directly with the type collection of Predynastic skulls in the Anatomical Museum of the Cairo School of Medicine, and also with skulls of the Fourth and Fifth Dynasties at Dr George Reisner's excavations (for Harvard University and Boston Museum) at the Giza Pyramids

It is hoped that the Committee will secure any further material that may be found by Mr Quibell during the coming season, and be able to fill up what has hitherto been the most serious lacuna in our knowledge of the physical characters of the ancient inhabitants of Egypt.

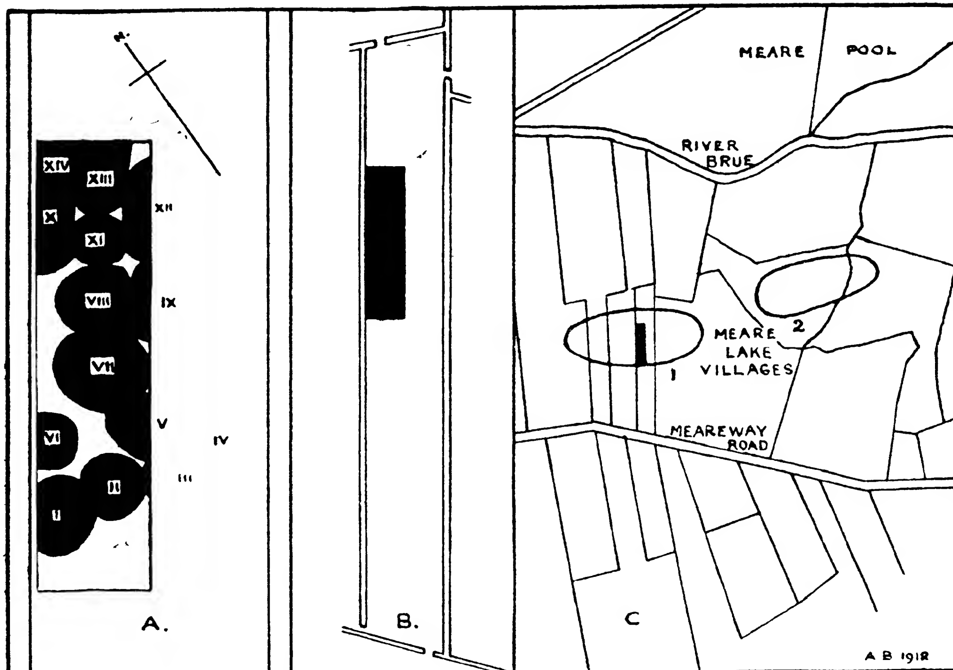
The Lake Villages in the Neighbourhood of Glastonbury —Report of the Committee, consisting of Dr R. MUNRO (*Chairman*), Professor W BOYD DAWKINS (*Secretary*), Professor W. RIDGEWAY, SIR ARTHUR J EVANS, SIR C HERCULES READ, Mr H BALFOUR, *and* Mr. A BULLEID, *appointed to investigate the Lake Villages in the Neighbourhood of Glastonbury in connection with a Committee of the Somersetshire Archæological and Natural History Society* (*Drawn up by* Mr ARTHUR BULLEID *and* Mr. H. ST GEORGE GRAY, *the Directors of the Excavations*)

THE third season's exploration of the Meare Lake Village by the Somersetshire Archæological and Natural History Society began on May 27, 1912, and was continued for three weeks under the joint supervision of Messrs Arthur Bulleid and H St George Gray The ground excavated was situated in the same part of the village and was directly continuous with last year's work

The digging included the examination of parts of the following mounds N E portions of Mounds X and XI , remaining from the excavations of last year, N quarter of Mound XII , and the S W portions of Mounds XIII and XIV

With the exception of Mounds XI. and XII , none of the above-

MEARE LAKE VILLAGES.



A Area excavated, showing sites of dwelling-mounds

B Field in which excavations were made, 1910–1912.

C Lake Villages, showing position of excavated area 6-inch scale.

mentioned sites appears to have been occupied for any length of time as dwellings, for neither wall-posts nor hurdles were discovered, and the clay floors were without the usual covering of black earth and charcoal. This no doubt accounts for the paucity of smaller finds during the season's digging. Mound XII contained two hearths, both of which were incomplete and in a poor state of preservation.

With reference to the construction of the mounds, several points of interest were noted, and foremost among these was the substructure under Mound XIII. This mound was supported by a massive foundation of logs and timber, of greater importance than any hitherto found at Meare. Apart from the strength and arrangement of the timber, the substructure yielded many pieces of worked oak and wattled hurdles. The latter included one complete hurdle and parts of five others. The complete hurdle measured 14 feet in length by 5 feet 6 inches in width. Amongst the pieces of worked wood were several mortised oak beams, three knobbed oak piles with sugarloaf-shaped heads, a wheel-shaped disc cut from a solid piece of oak, and a wooden handle belonging to some implement.

With reference to Mound X., a noteworthy feature was the large number of slabs of lias covering the surface of the upper floor.

Although the items of structural interest proved to be of considerable importance, the relics discovered were much less numerous than in previous seasons, and some of the clay floors examined did not appear to have been lived upon. The following is a summary of the objects found:—

Bone.—A very few pieces of cut bone of minor importance. Another worked shoulder-blade bone, with perforation, was found, bringing the total number of these objects up to thirty-nine.

Crucibles.—Seven items from Meare are now classified under this heading, including an almost perfect triangular specimen repaired this season, which has fused bronze adhering to the inner surface.

Bronze.—Five objects of bronze were collected this year, including a rivet-head and two spiral finger-rings, one being composed of two twisted strands of wire, the other ornamented like the fragment of a bracelet figured in 'The Glastonbury Lake Village,' vol. i., plate xlii., E 12.

Flint.—Six scrapers, two worked knives, and four other small roughly worked implements were found this season; also a large number of flakes, and several pieces of burnt flint.

Glass Beads.—Only one (with herring-bone pattern) was added this year, bringing the total up to twenty-eight.

Antler.—Few of the fragments of cut antler were of special interest, but an object covered with large dots and circles, presumably the greater part of a hair ornament, was found. Only one weaving-comb of this material was discovered.

Iron.—The few pieces of iron collected were in a bad state of preservation.

Kimmeridge Shale.—Part of a plain armlet and another worked fragment were added to the collection.

Querns.—An upper and a lower stone of rotary querns and fragments of others were found; also part of a saddle quern.

Other Stone Objects.—Several sling-stones, found singly, about twenty whetstones, a pounder, ten small smooth pebbles (perhaps *calculi*); and a few flat discs, not perforated. A stone socket, formed from a water-worn slab of lias, presumably for the support of a wooden post, was also found.

Spindle-whorls.—These objects have now reached a total of forty-five.

Baked Clay.—A few objects of baked clay were found, including parts of two triangular loom-weights, and some small balls, partly perforated.

Pottery.—The shards were not so abundant as in former seasons, but the proportion of ornamented pieces was perhaps larger than usual, and the greater part of some pots was found. The treatment of the curvilinear designs, herring-bone patterns, the trumpet patterns, and the dot-and-circle ornaments fully exemplify the skill and artistic feeling of the Late-Celtic potter. Most of the pots bear indented designs, and some are ornamented by means of potter's stamps and the roulette. Some of the pots are ornamented on the bottom, and several of the bases are perforated.

Animal Remains.—Large quantities of mixed bones of domesticated animals, for the most part broken small, were found in Mounds X. and XI., and on the first floor of Mound XIII. Few complete bones were dug up, and the remains of beaver, otter, and birds were not so plentiful this season.

A few hazel-nuts were discovered in the foundations, and fragments of charred bun-shaped 'cakes,' which await microscopical examination to determine the composition of the food.

The Age of Stone Circles.—Report of the Committee, consisting of Sir C. HERCULES READ (*Chairman*), Mr. H. BALFOUR (*Secretary*), Dr. G. A. AUDEN, Lord AVEBURY, Professor W. RIDGEWAY, Dr. J. G. GARSON, Sir A. J. EVANS, Dr. R. MUNRO, Professor BOYD DAWKINS, *and* Mr. A. L. LEWIS, *appointed to conduct Explorations with the object of ascertaining the Age of Stone Circles. (Drawn up by the Secretary.)*

THE work has been confined to the making of a careful survey plan of the earthwork and stones forming the Avebury stone circle, the grant of 15*l*. from the British Association having been applied for for this purpose. The survey has been made by Mr. H. St. George Gray, who was appointed by the Committee to carry out this work, which involved the completion of the survey of the whole monument, a portion of which

had already been plotted out by him in a previous year. The sum of 25*l*. was assigned to him for the expenses (including the fee for his own work), this sum being derived from the grant made in 1911 and the balance in hand from the previous account.

The plan includes all the ancient features and many of the modern ones which are included in the area covered by the survey. Those modern features which have been omitted can easily be filled in later if necessary, either from the 25-inch Ordnance sheet or from further original survey. Some buried stones not previously noticed have been included. The scale of the plan is 40 feet to the inch, and the whole is contained in six sheets, which will require to be mounted together.

Apart from this new survey supplying a really trustworthy record of the whole monument, it will prove invaluable as a plan upon which can be indicated with precision the exact areas which have been or may in the future be excavated for archæological purposes. Although the survey is completed, the plan is still in the rough, and it will require time to work it up into its final form, by inking and hill-shading.

It is very satisfactory to be able to state that certain difficulties which have hitherto prevented any excavations being conducted in the fosse to the east of the southern entrance-causeway appear to have been overcome, and that there is every probability of its being possible to investigate the eastern side of the causeway and to dig through the silting of the south-eastern portion of the fosse down to the original bottom. It is *very* desirable that excavations should be conducted on this side, the previous sections having been cut on the western side of this causeway. In order to enable this work to be carried out, the Committee ask for a grant of 45*l*. This amount will not suffice by itself, but if a grant of this sum is allotted it is very probable that this nucleus will be increased by subscriptions and that a fairly adequate fund may be raised. To this end the Committee ask for leave to apply for subscriptions, in the event of a grant from the British Association being given for the purpose.

The accounts show a small balance of 2*l*. 2*s*. 2*d*., which it is hoped may be allowed to be carried forward. There is a sum of 17*l*. 4*s*. 6*d*. also available, though this has been privately subscribed for the special purpose of cutting one or more sections through the *vallum*, and cannot be used for excavations in the fosse. The sum would be insufficient for any satisfactory excavation of the *vallum* unless excavations of a more extensive nature were possible at the same time, since the inevitable initial expenses would be too great in proportion to so limited an amount, if that alone were available. It is desirable that excavations in the fosse and through the *vallum* should proceed simultaneously, and it is hoped that the results will amply justify the assignment by the British Association of the grant applied for. A certain sum is required for the repair of damage done during excavation and for the making up of levels after the filling in of the portions excavated has had time to settle down compactly.

The possession of an accurate plan will greatly facilitate any further excavation which may be authorised upon this most interesting of British monuments. The Committee ask to be reappointed, with the

above-mentioned grant, for the purpose of further excavations upon the portion of the site suggested and, if the sum available suffices, for investigations upon other portions of the monument

---

Anthropological Photographs.—Report of the Committee, consisting of Sir C. H. READ (*Chairman*), Mr. H. S. KINGSFORD (*Secretary*), Dr. G. A. AUDEN, Mr. E. HEAWOOD, *and* Professor J. L. MYRES, *appointed for the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.*

THE Committee issue with this report a fourth list of photographs registered with them. The photographs have been taken by Mr. N. W. Thomas, Government Anthropologist, in Southern Nigeria. As the prints are not in the custody of the Committee, and are numbered according to Mr. Thomas's register, it has been considered advisable not to allocate a series of numbers in this particular case, as two sets of numbers would complicate reference, and it is impossible for Mr. Thomas to alter his own numeration.

SOUTHERN NIGERIA. EDO-SPEAKING PEOPLES. *Photographed by Mr. N. W. Thomas*, Government Anthropologist. (The prints are deposited at the Horniman Museum, Forest Hill, S.E.)

The locality to which each photograph refers is shown by the following list of places. The prints are classified under the scheme shown in the second list. The names are not repeated in this second list, as reference can be more easily made to the list of localities.

The topography of the district is shown in Mr. Thomas's 'Report on the Edo-speaking Peoples,' Part I.

LOCALITIES TO WHICH PHOTOGRAPHS REFER.

BINI

Edo	1–465, 980–1, 1177–87, 1353–64, 1517–26
Shelu	311, 312
Idumowina	315–374
Utekon	375–476
Ugo	1167–1176
Eviakoi	1188–1235
Iyowa	1236–1290
Iguichimi	1291–1323
Jeduma	1528–1543
Usen Road	1343–1352
Bini (not located)	1324–1342

KUKURUKU.

Ijeba	563–638, 640
Aroko	639–645, 647
Okpe	648–770
Otua	771–841
Sabongida	842–888, 896

KUKURUKU—*continued*

Ugboviato	889–895
Agbede	897–965
Fuga	1047–1112
Uzaitui	1113–1114
Agenegbode	1145–1157
Ewu	1544–1546
Ekwe	1547–1552
Iviare	1553, 1554
Yanipodi	1556–1560
Opepe	1561–1584
Kominio	1585–1611
Ouyiame	1612–1618
Soso	1619–1651
Semolika	1667–1707
Ibilo	1700–1733
Isua	1734, 1741, 1745

EŠA (ISHAN)

Irua	966–991
Ubiaja	992–1043

Sobo.	
Sapele	1365–1367
Okwoloho	1368–1372, 1373–1376
Eferun	1377–1389
Ajeyube	1390–1410
Ugeli	1411–1417
Ewu	1418–1422
Iyede	1423–1427
Agbasa	1428–1439
Jesse (A)	1440–1455
Kokori	1456–1461
Okpara	1462–1480
Ovu	1481–1492
Jesse (K)	1493–1501
Warifi	1502–1510

Sobo—*continued*	
Egori	1652–1666

Yoruba	
Ifon	466–502
Yoruba (not located)	978
Akoko	1736–1740
Owe	1747–1768
Jekri	1770
Ijo	1512–1516
Ibo and Ika	1159–1164
Niger Views	1044–1046, 1158

List for Arrangement of Classified Photographs

1. (*a*) Topography, (*b*) Farms.
2. Villages.
3. Houses
4. Physical Types, (*a*) Men, (*b*) Women
5. Children
6. Abnormalities
7. Skin-marks, Tooth-filing
8. Daily life
9. (*a*) Hair dressing, (*b*) Dress and Ornament
10. Market
11. Games
12. Dances
13. Technology.
14. Pottery.
15. Stone Implements
16. Decorative Art
17. Music
18. Ancestor Worship
19. Ceremonies and Ceremonial Objects.
20. Ebo and Gods
21. Magic.
22. Sacrifice.
23. Secret Societies.
24. Burial
25. Miscellaneous

List of Photographs Registered.

Topography

1612*b* View of Ouyiame
1632 Houses and rocks (Oloku)
1643*b* View of Soso
1643*c* „ „
1643*d* „ „
1679 View of Semolika
1687*a* Rocks and house under rock (Semolika)
1687*c* „ „ „
1704 View in Semolika

Farms

350 Farm with trees cut down
420 Garden farm
442 Burning down big tree
444 House on farm
445 „ „ beginning of
447 Yam stack

Villages

337 Outside house
349 Street in small village
362 Village scene.
431 „ „ (Utekon)
612*a* Houses arranged in square.
953*a* Entrance to town (Agbede).

Villages—*continued*

954 Street with pool of water for house building
983 Wooden houses arranged in squares
1391 Village path
1440*a* Scene in village
1595 Kominio square
1612 Scene in village.

Houses.

229 Making leaf roof.
312 Woman sitting in *oderie*
401 Wood house with leaf roof.
441 Mud house
655 House court at Okpe
691 Meeting-house (bundles of beans hanging from tree).
885 Wattle house.
1109 Round house (Kukuruku)
1361 European house built for native, Benin City (never used)
1384 Making house in Sobo country.
1453 Sobo house.
1510 Preparing mud for house.
1616 Entrance to house.
1484 Two-storied house.

PHYSICAL TYPES

Men.

43, 48, 87, 115, 136, 168, 170, 171*b*, 176, 176*b*, 177*a*, 177*b*, 178*a*, 178*b*, 179*a*, 179*b*, 180*a*, 181*b*, 182*a*, 182*b*, 183*a*, 183*b*, 184*a*, 184*b*, 185*a*, 185*b*, 186*a*, 186*b*, 187*a*, 187*b*, 188*a*, 188*b*, 189*a*, 189*b*, 190*a*, 190*b*, 192*a*, 192*b*, 193*a*, 193*b*, 194*a*, 194*b*, 195*a*, 195*b*, 196*a*, 196*b*, 197*a*, 197*b*, 198*a*, 198*b*, 199*a*, 199*b*, 200*a*, 200*b*, 201*a*, 201*b*, 202*a*, 202*b*, 203*b*, 219*a*, 219*b*, 220*a*, 220*b*, 221*a*, 221*b*, 222*a*, 222*b*, 223*a*, 223*b*, 224*a*, 224*b*, 226*a*, 226*b*, 237*a*, 237*b*, 238*a*, 238*b*, 239*b*1, 240*a*, 240*b*, 241*a*, 241*b*, 243*a*, 243*b*, 244*b*, 250, 256*a*, 256*b*, 257*a*, 268*b*, 272, 273, 274, 276, 277, 278, 281, 282, 292*a*, 293, 298, 300, 301*a*, 301*b*, 302, 303, 304, 375*a*, 375*b*, 376*a*, 376*b*, 493, 515, 525, 531*a*, 531*c*, 578, 588*a*, 595, 648, 649*a*, 650*c*, 651, 651*a*, 659, 685, 686, 729, 734, 735, 737, 744, 747, 748, 752, 776, 776*a*, 776*b*, 791, 792, 801, 802, 803*a*, 803*b*, 806, 806*b*, 808, 808*a*, 808*d*, 809*a*, 809*b*, 809*c*, 811, 811*b*, 811*c*, 811*d*, 812*a*, 812*b*, 825*a*, 825*b*, 825*c*, 847*b*, 847*c*, 847*d*, 851*b*, 851*c*, 852, 852*b*, 852*c*, 892, 897*b*, 897*c*, 898*a*, 898*b*, 898*c*, 899*a*, 899*b*, 899*c*, 900*a*, 900*b*, 939, 939*a*, 940, 941, 941*b*, 942*a*, 942*b*, 843*a*, 943*b*, 947*a*, 947*b*, 948, 962, 964, 975*a*2, 975*c*, 978*b*, 980, 981, 984, 985, 985*b*, 986, 991, 998, 999, 1031, 1032, 1048*a*, 1048*b*, 1048*c*, 1048*d*, 1048*e*, 1061, 1061*a*, 1061*c*, 1061*d*, 1061*e*, 1061*g*, 1065, 1068, 1071, 1076*d*, 1078*b*, 1078*c*, 1079, 1079*b*, 1079*c*, 1080, 1080*b*, 1080*c*2, 1082, 1105, 1153, 1184, 1185, 1186, 1186*a*, 1187, 1233, 1241, 1242, 1243, 1244, 1245, 1246, 1246*b*, 1246*c*, 1247, 1248, 1249, 1250, 1251, 1287, 1304*a*, 1315*a*, 1316, 1317, 1317*a*, 1318, 1329, 1330, 1331, 1331*a*, 1332, 1337, 1337*b*, 1338, 1338*b*, 1338*c*, 1339*b*, 1339*c*, 1340*a*, 1340*b*, 1341, 1341*b*, 1341*c*, 1342, 1342*b*, 1342*c*, 1353, 1354, 1355, 1359, 1359*a*, 1362, 1363*a*, 1363*b*, 1365, 1365*b*, 1365*c*, 1368, 1368*a*, 1369, 1369*a*, 1370, 1387*a*, 1388*a*, 1404, 1404*b*, 1404*c*, 1405, 1405*b*, 1405*c*, 1406, 1407, 1407*c*, 1408, 1408*a*, 1410*c*, 1412, 1412*c*, 1413, 1413*b*, 1413*c*, 1420, 1420*a*, 1420*b*, 1421, 1421*a*, 1422*a*, 1422*b*, 1424*a*, 1424*b*, 1425, 1425*a*, 1426, 1426*a*, 1427, 1427*a*, 1428, 1429, 1429*a*, 1430, 1430*a*, 1431, 1432, 1432*a*, 1432*d*, 1433, 1433*a*, 1434*a*, 1434*b*, 1435, 1435*a*, 1436, 1436*a*, 1437, 1437*a*, 1438, 1438*a*, 1439, 1439*a*, 1447, 1448, 1448*a*, 1458, 1458*a*, 1459, 1459*b*, 1460, 1460*a*, 1471, 1492, 1492*b*, 1493*a*, 1502, 1502*a*, 1503, 1503*a*, 1504, 1504*a*, 1516, 1517, 1518, 1519, 1520, 1521, 1522, 1523, 1524, 1525, 1526, 1527, 1554, 1554*b*, 1561, 1562, 1563, 1564, 1585, 1587, 1594, 1596, 1621, 1622, 1623, 1625, 1630, 1631, 1646*a*, 1650, 1652*a*, 1652*b*, 1652*c*, 1653*a*, 1653*b*, 1654, 1655, 1661*b*, 1667*a*, 1667*c*, 1668*a*, 1668*c*, 1674*c*, 1708*b*, 1711*b*, 1714*b*, 1715*b*, 1716*a*, 1746, 1746*a*, 1752

Women.

74, 85, 129, 130, 131, 242*a*, 242*b*, 269*a*, 287, 305*a*, 306*a*, 306*b*, 383, 384, 388*b*, 388*c*, 402, 404, 405, 406, 407, 408, 409, 410, 411, 452, 458, 505, 526, 527*a*, 527*b*, 529, 530*a*, 530*b*, 533*a*, 533*b*, 533*c*, 534*a*, 534*b*, 534*c*, 586, 591, 592, 593, 603, 614, 617, 658*b*, 666, 682, 718, 719, 721, 723, 728, 738, 739*b*, 740, 742, 745, 746, 749, 750, 751, 753, 758, 762, 763, 763*d*, 771*b*, 771*c*, 771*d*, 772*b*, 773*a*, 773*c*, 773*d*, 774*a*, 774*b*, 775*a*, 775*b*, 777*a*, 777*b*1, 777*b*2, 777*c*, 777*d*, 778*e*, 811, 819*a*, 819*b*, 820*a*, 820*b*, 821, 821*b*, 823*a*, 823*b*, 853*a*, 853*b*, 853*c*, 854, 854*b*, 854*c*, 855, 902*a*, 902*b*, 902*c*, 914*a*, 914*b*, 914*c*, 915*a*, 915*b*, 916*a*, 916*b*, 917, 918, 918*b*, 919*a*, 920, 921, 922*b*, 923*a*, 923*b*, 924, 924*b*, 924*f*, 984, 989, 989*a*, 1009, 1032, 1035, 1038, 1038*a*, 1047, 1047*c*, 1047*d*, 1060, 1066, 1070*a*, 1084, 1084*b*, 1084*c*, 1085, 1085*b*, 1085*c*, 1087, 1087*b*, 1087*c*, 1098, 1103*g*, 1117, 1117*c*, 1124, 1171*b*, 1216, 1217, 1218, 1219, 1219*a*, 1230, 1231, 1235, 1239, 1251, 1324, 1326, 1327, 1330*b*, 1336, 1356*a*, 1356*b*, 1357, 1357*a*, 1366, 1366*a*, 1366*b*, 1367, 1367*b*, 1371, 1380, 1387, 1388, 1410*b*, 1410*b*2, 1410*d*, 1410*g*, 1411, 1411*a*, 1411*b*, 1412*b*, 1418, 1418*a*, 1419, 1419*a*, 1423*a*, 1423*b*, 1441*a*, 1441*b*, 1442, 1443, 1444, 1445, 1445*a*, 1446, 1446*a*, 1451, 1456, 1457, 1461, 1461*b*, 1481, 1488*b*, 1489, 1489*a*, 1489*c*, 1490, 1490*b*, 1490*c*, 1491, 1491*b*, 1491*c*, 1492, 1495, 1505, 1505*a*, 1505*b*, 1507, 1507*a*, 1507*b*, 1538*b*, 1538*b*2, 1538*b*3, 1550, 1553*a*, 1553*b*, 1553*c*, 1553*d*, 1553*e*, 1553*f*, 1553*g*, 1553*h*, 1553*j*, 1583*a*, 1583*b*, 1583*c*, 1590, 1593, 1615*a*, 1615*b*, 1619, 1626*a*, 1627*b*, 1633, 1634*a*, 1634*b*, 1637*a*, 1637*b*, 1638*b*, 1638*c*, 1638*d*, 1639*c*, 1640*b*, 1640*h*, 1644*a*, 1644*b*, 1645*a*, 1645*c*, 1645*e*, 1647*a*, 1647*c*, 1649*a*, 1649*b*, 1651, 1657*a*, 1659*b*, 1660, 1661*a*, 1663*a*, 1723, 1824*a*, 1727, 1728*a*, 1728*b*, 1729, 1730.

Children.

35, 275, 365, 367, 418, 426, 436, 454, 453, 456, 457, 460, 461, 462, 466, 466*b* (Utekon), 517, 564, 565, 573, 577*b*, 582, 584*a*, 604, 618, 622, 623, 623*a*, 624 (Ijeba), 684 (Okpe), 741, 788*e*, 789*a*, 789*d* 789*c*, 790*a*, 790*b* (Otua), 883, 965, 973, 987, 988, 990, 996, 1003*i*, 1006, 1020

PHYSICAL TYPES—*continued*

1064, 1069, 1083, 1083*a*, 1097, 1122, 1138, 1234*a*, 1235, 1240, 1245, 1319, 1322, 1323, 1325, 1377, 1380, 1389, 1389*a*, 1389*b*, 1410*b*, 1433, 1433*a*, 1436, 1436*a*, 1437, 1437*a*, 1438, 1438*a*, 1447, 1449, 1461, 1461*b*, 1505, 1508, 1508*a*, 1509, 1511, 1532, 1535, 1550*a*, 1554, 1620, 1624, 1656, 1665, 1672, 1725, 1726*c*

ABNORMALITIES AND DISEASES

284 Hydrocephalic boy (Benin City)
285 ,, ,, ,, ,,
286 ,, ,, ,, ,,
581 Girl with strabismus (Ijeba)
646 Boy with umbilical hernia (Benin City)
686 Malformation of foot (Okpe)
736 Boy with light coloured eyes (Okpe).
950 Girl with supernumerary *mamma*
950*b* ,, ,,
950*c* ,, ,,
950*d* ,, ,,
952 Albino (girl)
952*a* ,, ,,
952*b* ,, ,,
952*c* ,, ,,
952*d* ,, ,,
955*b* Albino, with marked back.
969 Leucoderma
969*a* ,,
969*b* ,,
969*c* ,,
1358 Yaws
1358*a* ,,
1360 Diseased prisoner
1647*c* Boy with umbilical hernia.
1661 Malformed arms (Gori)

SKIN-MARKS.

Woman.

Face, 1505, 1505*a*
Face and chest, 1366, 1366*a*, 1412*b*, 1441*b*, 1444, 1445, 1455*a*, 1446
Face, chest, and neck, 1367, 1367*b*, 1387, 1387*a*
Chest decoration, 388*a*, 505, 1127, 1371, 1371*b*, 1481
Neck decoration, 1367*c*.
Back decoration, 650*a*, 1366*c*, 1538.
Body marks, 288*a*, 288*b*, 289*a*, 289*b*, 290, 290*a*, 1169, 1169*a*, 1170.

Man.

Face, 847*b*, 847*c*, 1369, 1369*a*, 1408*a*, 1431, 1439 (boy).
Face and neck, 1365.
Face and chest, 1365*b*, 1388, 1388*a*.
Face and arms, 1430*a*.
Chest, 1052, 1052*a*, 1078*b*.

SKIN-MARKS—*continued*

Arms, 1425, 1425*a*.
Back, 1365*a*.
Body marks, 629.

Body-painting.

Black marks, 1070, 1070*a*.
Painting, 1072.

TOOTH-FILING.

Men.

639, 762, 900, 975*d*, 1365*c*, 1412*c*.

Women.

822*a*, 822*b*, 1492*a*.

DAILY LIFE.

Loads (Men).

97 Boys on road.
688 Old man carrying sticks.
824 Boy with palm-oil pot.

Loads (Women).

33 Girl standing in doorway.
94 Woman on road.
122 Girls of Benin city.
134 Woman on road
209 Women and babies.
364 Street scenes at Idumowina
366 Baby and mother
373 Woman and child before Olokun in Egwaibo, Idumowina.
374*a* Child, ditto.
374*b* ,, ,,
385 Girls talking.
423 Girl with waterpots.
435 Girl bathing.
451 Climbing palm-trees.
554 Spinning cotton.
555 Washing yams.
567 Girl carrying fufu.
591 Children playing.
602 Girl with basket.
619 Mother with child with waterpots.
656 Girl sitting outside house
1149 Women with load of wood.
1150 Women with loads.
1152 ,, ,,
1229 ,, ,,
1410*a* ,, ,,
1410*b* ,, ,,
1486 ,, ,,
1565 ,, ,,
1577 ,, ,,

Daily Life.

661 Men sewing (Okpe).
661*b* Shaving the head.
663 Washing clothes.

Daily Life—*continued.*

667 Sheep with necklace as property mark.
679 Men winding thread.
689 Midday rest.
711 Women with food.
780 Courtyard of a house.
781 Outside of a house.
788*a* Women preparing to break palm-kernels.
805 Men talking.
806*b* Old men talking.
844*b* Gang of chiefs
861 Mashing yams.
966*a* King's wives at Irua.
970*c* ,, ,, ,,
994*a* ,, ,, bathing at Ubiaja.
994*b* ,, ,, ,, ,,
1023*a* Boy bathing.
1032*a* Sitting outside a house
1040 Small boy eating.
1043 Pounding fufu
1118 Breaking palm-kernels
1134 Man bathing
1378 Women drawing water from well
1382 Woman grinding cassava
1391*a* Spectators.
1485 Man sleeping
1494 Girls pounding fufu
1533 Sitting outside house
1537 Woman outside a house
1648 Man making hat.
1686 Sitting on the rock.

Hair-dressing.

Process.

412, 413, 416, 417, 1011*b*, 1011*d*

Styles.

On shape Men, 1459, 1459*b*; Women, 821, 848*a*, 848*b*, 922, 925, 925*b*, 974, 974*a*, 1011*a*, 1011*c*, 1538, 1538*b*, 1538*b*2
Braided Women, 599*a*, 1047
In thrums Men, 1448, 1448*a*, 1458, 1458*a*, 1504, 1504*a*.
In circles on crown Men, 1421, 1421*a*, 1425, 1425*a*
Head partly shaved Men, 1132, 1422*a*, 1422*b*, Women, 1419, 1419*a*.
With band round head · Men, 1412*a*, 1420, 1420*a*
Arranged in clumps · Women, (*a*) 1159*b*, 1456, 1459, (*b*) 919*b*, 921*b*, 922*b*, 973, Men (*a*) 1405*b*, 1405*c*, 1424*a*, 1424*b*, 1426, 1426*a*, 1430, 1430*a*.

Dress.

317*a* Priest of Osa.
317*b* ,, ,,
813 Woman with brass collar.
813*a* ,, ,, ,, ,,
813*b* ,, ,, ,, ,,
813*c* ,, ,, ,, ,,
882 Chief in war-dress.
1106 Woman with ivory anklets.
1427 Cowry necklace.
1427*a* ,, ,,
1475 Priestess of Olokun.

Market.

15 Pottery in market.
190 Full market
207 Small market.
208 Mat-making in market
665 Daily market, Okpe
665*b* Woman in market
676 ,, ,, ,,
676*b* ,, ,, ,,
1113 Small market
1140 Big market
1140*c* Counting cowries
1155*c* Market scene
1155*d* Bargain for beans
1155*g* Market scene
1155*k* Market hat
1639*a* ,, scene
1639*b* ,, ,,
1639*c* ,, ,,
1640*b* Sitting outside market
1640*c* Market scene
1640*m* ,, ,,

Games

Boys

341 Wrestling
342 ,,
343 ,,
871 Osi.
871*c* ,,
872 Agbagagba ([1])
874 ,,
875 Egegalogembe
876 Ekpemewe
877 Alauxala
878 Opehulele
879 Dobodariaria
880 Lelelelebelue
880*a* ,,
903 Anunganunganu (prisoner's base).
903*b* ,, ,, ,,
904 Guagua okino (circling under arms).
905 Alaikana (trying hands of circle).
906 Dedemudekaia (leg over head).
906*a* ,, ,, ,,

[1] The description of these games has not yet been published.

GAMES—*continued.*

907 Kpegege (somersault in circle)
908 Perıupupıle (passing through legs of lıne)
909 Orokuekue (walkıng on hands to pass through legs of circle)
910 Asınabanaba (pushıng).
911 Amıouılızılota (passing on hands)
912 Kekekeke or Amenaıkazı
913 Ogue (prısoner's base, second form)
1174 Ukponagbe
1174*a* „
1191*a* Olawolo.
1303 Omodo ogılorholomı (ball on legs)
1381 Playıng Ise
1566 Wrestlıng (Une)
1567 Head wrestlıng (Ogbo)
1567*a* „ „ „
1567*b* „ „ „
1567*c* „ „ „
1567*d* „ „ „
1567*e* „ „ „
1567*f* „ „ „
1570 Standıng on head
1576 Ikolı (rollıng from side to side)
1605 Ozıakpela (pullıng rod)
1606 Iafebedako (shakıng leg)
1607 Elamakele (duckıng)
1608 Ikuekona (rollıng)

Girls.

453 Gırls playıng
930*a* Ega
930*b* Ewe
930*c* „
931 Ekolona
932 Ogonıolulu
933 Omoıgbe
934 Oıaluke Sakbolele
935 Asaııo.
935*a* „
936 Game
1172 Tagame (aku)
1173 Akpakpa
1173*a* „
1176*b* Uke
1188 Olato (at Evıakoı) (throw-off cloth)
1188*a* „ „ „
1189 Orhomı
1190 Aıze (rıng and step over hands)
1192 Emorıude (countıng out)
1193 Ekızı (each player walks round, all band, sıng, jump up)
1194 Adamukıele (paırs clap hands).
1195 Omıwo (rıng of hands)
1196 Tukpe (end-groups may breathe whıle others run across)
1197 Ilakbolologıeme (two partıes rub ground wıth hand).
1198 Ovıugıe.

GAMES—*continued.*

1200 Bikoko za (beat hands on ground, player touches one)
1201 Ukponagbe (cloth game)
1202 Ivıloberoma (hıdıng object and lookıng)
1203 Elemule (palm-kernels)
1204 Ogıeıomomebıe (lıne of gırls, first pulled out)
1204*a* „ „ ,
1296 Carryıng sand to Egmo.
1297 Rope pullıng
1298 Kızı
1299 Carryıng boy on shoulders.
1300 Yam game
1300–1 „ „
1300–2 „ „
1300–3 „ „
1300–4 „ „
1300–5 „ „

DANCES.

576 Dancıng
571 Chıldren
577 „
577*b* „
967*a* Kıng's wıves.
967*b* „ „
967*c* „ „
1001 Dancıng gırl
1026*a* „ „
1058 Dance festıval
1058*b* „ „
1059*a* „ place.
1156*a* Dancıng
1156*c* „
1462 Oloku dance.
1463 „ „
1464 „ „
1465 „ „
1466 „ „
1467 „ „
1468 „ „
1489 „ „
1555 Gırls dancıng
1555*b* „ „
1555*c* „ „
1555*d* „ „
1578 Woman dancıng
1582*d* Gırls dancıng
1582*e* „ „
1582*f* „ „
1582*j* „ „
1582*r* „ „
1582*s* „ „
1582*t* „ „
1582*u* „ „
1583 Small gırls dancıng.
1603 Women dancıng.
1609*b* Gırls dancıng
1609*c* „ „
1609*d* „ „
1609*e* „ „

Technology.

Archery : 993, 1386.
Canoe : 1484.
Carved Figures 1000, 1003, 1007, 1545*a*.
Carving Drums, 804, 833, 864, 1108, Doors, 1092 (in stone), 1480
Looms · Woman's, 508, 509; Man's, 827; Woman's, 857; Man's, 1617
Making string 1258
Materials for body-marking: 49
Metalwork · Old bell, 156; Iron furnace, 1610*a*, 1610*b*
Plaiting-bag · 139
Spinning cotton · 570, 576*b*, 1013, 1041, 1125
Traps · Deer-trap, 645, Fish-traps, 1482, 1482*a*.
Winding cotton · 856, 959*a*
Palm-oil making · 316*b*, 1675*a*, 1677, 1704, 1704*b*, 1704*d*, 1704*e*, 1704*f*, 1704*h*
Palm-oil pit 684
Position for childbirth 1130*c*

Pottery.

Pots

828 Pots in Otua
1177 Ulo Olokun pot.
1179 Ukodo pot
1180 Uwawa, oviaxe (two pots).
1181 Ulu ebo, oviaxe (two pots)
1182 Axe for yams
1183 Ukodo pots

Making Pots.

377*a*, 377*b*, 379, 380, 381, 382, 398*a*, 398*b*, 399, 845*d*, 845*f*, 846*b*, 846*c*, 846*e*, 846*f*, 846*g*, 846*h*, 849, 849*a*, 849*b*, 849*c*1, 849*c*2, 849*d*, 849*h*, 858, 859, 860

Stone Implements.

81*a*, 81*b*, 157, 158, 1208, 1210, 1210*b*.

Decorative Art.

40 House in Benin City.
164 Shrine of Obalifon
165 Rosette, &c, on wall
166 Interlacing pattern on wall
766 Wall-painting, Okpe.
766*a* ,, ,,
893 House decoration.
976 Geometrical decoration, house
799*b* Carving of Esu on door
1025 Carved doors.
1027 ,, ,,
1611 ,, ,,
1664*a* ,, ,,
1664*b* ,, ,,
1685 ,, ,,
1114 Boy's drawings on wall.

Decorative Art—*continued.*

1165*a* Scroll-work on house.
1166 ,, ,, ,,
1207 ,, ,, ,,
1213 ,, ,, ,,
1214 ,, ,, ,,
1345*b* Circles, &c, on house.
1349 Animals in relief.
1528*a* ,, ,,
1529 Scroll-work and wall-painting
1543 Painted wall.
1551 Lizards.

Music.

503*a* Musical box.
635 Calabash flute.
636 Midrib of palm (played with calabash and stick)
657*a* Boy with guitar
701 Drum.
971 Instruments at Irua.
981 Alagiata.

Ancestor Worship.

73 Father's shrine at chief Ini's house, Benin City.
132 Idion of quarter, Benin City
150 Shrine of father, Ojumo's house
155 ,, ,, ,, ,,
159 ,, ,, ,, ,,
160 ,, ,, ,, ,,
161 ,, ,, ,, ,,
162 Ogwedion of Uzebu (for the worship of ancestors)
163 ,, ,, ,, ,,
335 Ogwedion of Idumowina
351 Idogbo or Idion of farm
353 ,, ,, ,,
439 Uxure of Ovia.
450 Pots put down in the road by men who have not yet buried their fathers (Utekon)
546 Ikut, Ikute, or at Uxure in Ijeba
1039 Stool used for worship of father (Ubiaja)
1054*a* Place for the worship of the father (Fuga)
1055 Place for the worship of the mother
1479 Father's shrine (Okpara, Sobo).
1498 Uxure of Olokun (Jesse).

Ceremonies and Ceremonial Objects

230 Salutation for Ojumo, Benin City.
394 Ceremony of purification, Utekon.
396*a* ,, ,, ,,
396*b* ,, ,, ,,
519 Oxidari and ceremonial gate, Ijeba.
814*a* Ukbe festival.
816*a* ,, ,,
816*f* ,, ,,

CEREMONIES AND CEREMONIAL OBJECTS—*continued.*

816*h* Ukbe festival.
816*k* " "
816*l* " "
818*a* " "
818*b* " "
818*c* " "
818*d*1 " "
818*d*2 " "
867 Elegbo for taking oath.
892*a* Bark dish for sacrifice.
1088 Masks.
1093 Aba cord to separate the room of a woman who has borne a child
1101 Ceremonial spear.
1102 Place for the induction of chiefs.
1128 Mourning, white, yellow.
1135 Gate with medicine and side entrance.
1257 Whirling a bull-roarer.
1364 Carrying Ake to find a thief.
1364*a* " " "
1372 Sobo women on return from sacrifice.
1385 Sick woman outside Sobo shrine
1403 Drum.
1464 Dance for Olokun
1469 " "
1472 Awana and Ovo
1557 Girl in marriage-dress
1559 " " "
1559*c* " " "
1732 Ofuno drums and mask.
1733 " " "

EBO AND GODS.

39 Ake on wall of house
125 Ake.
322 Ojumo of Ake.
324 Ake.

333 Ake Nogidia.
124 Olokun.
144 "
154 "
321 " image at Idumowina.
1293 " (with movements).
1454 "
1496 Uxure of Olokun.
1497 Olokun.
1499 "
1534 "
1538*b* "
1539 "
1543 "

135 Esu.
145 "
152 "
668 "
680 "

EBO AND GODS—*continued.*

726 Esu.
799*a* "
1337 "
1379 "

141 Ogun.
142 Oxwaiye.

142 Osa.
149 "
539 Ubawiti and house of Osa.
540 " " "
675 Osa and Osun.
868 "
1107 "
1111 "
1115 "
1335 " and Idion.
1383 "

334 Aluoto, the earth.
732 Obwada—alu oto (tree).
863 "

151 Entrance gate to which tortoise was offered
153 Osun.
296 Osunematon.
314 Shrine of the hand.
325 Odumha.
326 Lamp-holder.
327 Blacksmith.
328 Doorkeeper's captain.
331 Drummer.
352 Omaiho.
422*a* Akobie.
425 Oxwaiye.
440 Uxure of Ovia.
644 Stones worshipped by chiefs.
671 Osun.
783 Hunter's shrine (where he puts gun on returning).
798 Isemegbe (to keep away sickness)
826 Ukpewole (small stove to which sacrifice is offered).
831 Ebọ of the fields.
845 Obewutoli.
862 Adabi.
865 Abofi.
866 Ohimixidion (founders of village).
869 Ugwenabo.
870 "
889 Omweki.
890*a* Priest of Omweki.
992 Urholi (to keep alive)
1030 Osun Ogboma.
1050 Imobe.
1063 Osalobula.
1089 Uloko.
1137 Eho.
1167 Osun.

EBỌ AND GODS—*continued.*

1206 Oxwaiye.
1211 Uxure.
1211*b* Oxwaiye.
1295*a* Ovia erua
1295*b* ,, ,
1334 Osun.
1373*a* Nurie.
1373*c* ,,
1374 ,,
1374*a* ,,
1375 ,,
1376 ,,
1394 Nama.
1394*a* ,,
1394*b* ,,
1395 ,, house.
1396 ,,
1397 Amyata
1398 Uriemi.
1399 Oraime.
1401 Ogene.
1402 Ora.
1413*d* Ogene.
1414 ,,
1415 ,,
1450 Ora.
1452 Oragodo (small pots).
1473 Oku.
1474 Orhirhie.
1477 Shrine outside village.
1478 ,, ,, ,,
1500 Images.
1528 Ovato.
1528*a* ,,
1529 ,,
1530 Wood for festival.
1531 Oleha.
1547 Omogba, to save.
1548 Ole, to save.
1678 Isiokumi.
1689 Eho.
1731 Iku

MAGIC.

230 Magic against sickness and fire.
449 ,, ,, leopard.
500*b* Medicine against leopard.
524 Izobo for purification.
632 Medicine.
643 ,, for fields
669 ,, to keep off sickness.
700 Eka medicine.
702 Medicine in house court.
703 Agwe medicine.
787 Medicine in square.
794 Ekenado (to keep thieves from market).
884 Farm medicine.
894 Medicine.
977*a* ,, to keep off rain.
977*a*1 ,, ,, ,,

MAGIC—*continued.*

977*a*2 Medicine to keep off rain.
982 ,, ,, ,,
1112 Ogbe (to wash feet of travellers).
1114 ,,
1136 Ogoluhu (to keep away sickness).
1141 Ogbe
1294 Witch-tree.
1400 Evi.
1455 Medicine to keep away smallpox
1540 Ekosi
1681 Medicine-house.

SACRIFICE.

297*a* Sacrifice to Ehi.
297*b* ,, ,,
830 Place for sacrifice to Ekosi.
1470*a* Sacrifice to Olokun.
1471 ,, ,,
1618*a* Sacrifice

SECRET SOCIETIES

357 Egbo for small boys
795 Eliminia.
796 ,,
797 Edebenia.
800 ,,
815 Eliminia dress.
834 ,, ,,
835*a* ,, ,,
836*a* ,, ,,
837*a* ,, ,,
839*a* ,, ,,
840*b* ,, ,,
886 ,, masks.
888 ,, ,,
889 ,, ,,
1099 Net mask
1252 Entrance to Ovia house
1253 Uxure.
1258 Ovia dancing, first day.
1260 ,, ,, ,,
1261 ,, ,, ,,
1264 ,, dress
1267 Offering cowries
1272 Ovia's head-dress
1280 Entrance to Ovia house.
1281 Foundation of hat
1282*a* Back of Ovia house.
1289*a* Carrying materials, women have to leave street.
1289*f* Dancing, second day.
1290*d* ,, ,,
1290*f* ,, ,,
1343 Old dresses outside Ovia house.
1345 Ovia dress.
1346 ,, ,,
1347 ,, ,,
1348 ,, servant.
1409 Masker at Ekowari.

SECRET SOCIETIES—*continued.*

1409*a*	Adaubi.
1555*c*	,,
1556	,,
1556*a*	,,
1556*b*	,,
1556*c*	,,
1558*a*	,,
1560	,,
1579	Masker at Opepe
1580	,, ,,
1641*b*	Masker at Soso
1642	,, ,,

BURIAL

1131	Burial-place of young man
1142	Bier.
1688	Burial-ground for old people
1734, 1734*a*, 1734*h*, 1734*i*, 1734*k*, 1734*m*, 1734*t* 1734*u*, 1734*x*	Burial-dance. Hunter's burial.

MISCELLANEOUS.

434*a*	Group
692	,,
1391	,,
1417	,,
1440	,,
1546	,,
1546*a*	,,
1549*b*	,,
1550	,,
1550*a*	,,
5	Woman lamenting burning of house, arms on level with waist.
429	Cradle on palm tree for offering when it bears.
841	Method of holding spear for war
1057	Medicine for witches
1129	Pot in tree for collecting honey.

Notes and Queries in Anthropology.—Report of the Committee, consisting of SIR C. H. READ (*Chairman*), Professor J. L. MYRES (*Secretary*), MR. E. N. FALLAIZE, DR. A. C. HADDON, MR. T. A. JOYCE, *and* DRS. C. S. MYERS, W. H. R. RIVERS, C. G. SELIGMANN, *and* F. C. SHRUBSALL, *appointed to prepare a New Edition of 'Notes and Queries in Anthropology.'*

THE Committee report that the manuscript for the new edition was sent to the printer in June last, and that the book should be ready for publication in September. The grant of 40*l.* made by the British Association was paid on account of printing in progress at the end of June, and it is expected that the proceeds of the sale of the previous edition will approximately cover the rest of the expense of producing the new one. It has not, however, been possible to close the accounts in time for the Dundee Meeting, and the Committee ask to be reappointed, with a small grant in the event of a deficit.

A Prehistoric Site at Bishop's Stortford.—Second Report of the Committee, consisting of Professor W. RIDGEWAY (*Chairman*), Rev. Dr. A. IRVING (*Secretary*), Dr. A. C. HADDON, *and* Dr. H. W. MARETT TIMS, *appointed to co-operate with a Local Committee in the Excavation thereof.* (*Drawn up by the Secretary.*)

IT has not been found possible to continue the excavations on the exact site where the horse-skeleton was found, but other parts of the same

hill-flank have been further opened up in excavations for building purposes

A A road-cutting up the breast of the hill on the western side has exposed the *rubble-drift*, in which gravel was seen driven in pockets into the contorted London clay (to depths of two feet or more) on the breast of the hill

B On the eastern side, at about 280 feet, O D, building excavations have exposed the *rubble-drift* on the hill-slope, the sections passing down into undisturbed London clay The suite of 'finds' in this rubble-drift includes —

> *Bones of Horse*—two broken rather small *metacarpals* (too incomplete for exact measurement), perforated upper end of *tibia* showing marks of a (bronze?) hatchet
>
> *Bones of Ox*—complete *metatarsal*, two fragments of *tibia* (one the upper, the other the lower half of the bone), *humerus* (lower end), two *metacarpals* (lower end), upper half of *radius* (with the ulna detached)
>
> *Bones of Sheep*—left *mandible* (dentition well preserved)

Also several fragments of ribs of either ox or horse, too imperfect for identification All these fragments are in an advanced stage of decay, probably from surface exposure previous to their inhumation One or more of them bear the marks of teeth of some carnivorous beast

In most cases the conditions of the fractures lead to the belief that the bones were violently fractured as if for the extraction of the marrow

> Fragment of primitive (neolithic?) tile
> Fragment of coarse (neolithic?) pottery
> Three (or four?) worked flints, including one blunted scraper

One *scaled* flint (see 'Report' 1911) from the Boulder clay and a *Gryphaea incurva*

The 'finds' were mostly met with at from one and a half to two feet from the surface

Anæsthetics—Fourth Interim Report of the Committee, consisting of Dr A D WALLER (*Chairman*), SIR FREDERIC HEWITT (*Secretary*), Dr BLUMFELD, Mr J A GARDNER, *and* Dr G A. BUCKMASTER, *appointed to acquire further knowledge, Clinical and Experimental, concerning Anæsthetics—especially Chloroform, Ether, and Alcohol—with special reference to Deaths by or during Anæsthesia, and their possible diminution.*

THE Committee has met four times during the past year, and has continued to make observations and experiments in estimation of the

anæsthetic power of ether with special reference to the clinical procedure known as 'open ether administration'

The Committee desires to be reappointed for the coming year, at the end of which it is intended to present its final report

---

Calorimetric Observations on Man.—Report of the Committee, consisting of Professor J S. MACDONALD (*Chairman*), Dr. G. CHAPMAN (*Secretary*), *and* Dr KEITH LUCAS, *appointed to make Calorimetric Observations on Man in Health and in Febrile Conditions.* (*Drawn up by the Chairman*)

IT was our original intention to conduct a series of experiments, first upon normal subjects and later upon subjects in definitely febrile conditions, but at the commencement of the year I was unfortunate in losing the co-operation of Dr Chapman owing to his assumption of the duties of a new and busy post, and have therefore confined my attention to the normal subject Numerous experiments have been carried out with the calorimeter previously described, but with some little alteration in technique, as in the insertion of a fan within it to produce a thorough admixture of its air content, and the substitution of wet and dry bulb readings for the process of absorption with sulphuric acid, and weighing, which was used at first to estimate the excess aqueous vapour leaving the calorimeter

In each experiment the following sets of observations have been made every five minutes, in a definite order more or less closely adhered to —

(*a*) The temperature of the water entering, and that of the water leaving, an internal radiator system placed beneath the roof of the calorimeter

(*b*) The resistance of some 600 ohms of iron wire placed in three coils close to the walls of the calorimeter, and dealt with as giving the mean temperature of its walls and the basis for corrections due to variations in this temperature

(*c*) Temperatures indicated by wet and dry bulb thermometers in the room air and by similar thermometers placed in the air stream passing from the calorimeter to the suction pump determining its air-supply

(*d*) The current in, and voltage across, the variable incandescent lamps and fan, &c , placed within the calorimeter, so that a subtraction might be made for their value as an accessory source of heat

(*e*) The current in the electrical brake of the cycle ergometer

(*f*) The number of revolutions of the cycle as registered upon an automatic 'counter'

(*g*) The galvanometric deflection due to a thermo-couple (rectal) giving the deep temperature of the subject

(*h*) The galvanometric deflection due to another similar thermocouple (skin) giving the surface temperature of the subject.

In addition, the weight of the water leaving the internal radiator system of the calorimeter was measured at intervals of time determined by the rate of water-flow and the complete filling of a pan placed upon one arm of a balance

From observations (*a*), (*b*), (*c*), (*d*) the *heat-output* of the subject (*plus* any heat arising from a subsequent conversion of mechanical work into heat) was calculated for each five-minute period and the results plotted as curves By correction from observation (*g*) these curves, altered by allowances for the storage of heat in the subject, were converted into *heat-production* curves—that is to say, curves representing the total transformation of energy within the calorimeter

This endeavour to obtain results capable of erection into curves showing variations corresponding with such short time intervals has been unexpectedly justified by coincident observations of the temperature of the subject's surface from which the heat is mainly passing into the calorimeter. *The curves of heat output obtained by the complicated addition of data from observations* (*a*), (*b*), *and* (*c*), *and by subtraction of data from observations* (*d*) *are parallel to the surface temperature curves obtained simply by one set of observations* during the first half-hour of each 'work experiment,' that is to say, so long as the observations of surface temperature are not complicated by the accumulated presence of surface moisture, and in some of the extremely light 'work experiments' continue in parallel fashion to the end of the experiment whilst showing corresponding variations at nodal points

This confirmation of the value of these curves brings into greater prominence the fact that the 'heat-output' curves, and even the 'heat-production' curves—which latter represent an attempt to describe the total transformation of energy within the calorimeter—rise gradually for the best part of an hour to summits that are then more or less maintained during any further period of continuance in the performance of uniformly maintained mechanical work—a fact upon which I have elsewhere commented It would thus seem as if the transformation of energy per unit of mechanical work performed was a quantity that increased up to a certain value which was then maintained, and that the 'efficiency' of man as a machine varied in this fashion with the time spent in work

This may be the case, but is improbable as not supported by evidence obtained by other observers in different ways—as by the quantitative examination of the carbonic-acid output If it is not the case, then two other lines of explanation have in addition to be examined Thus it may be that the 'deep temperature' (rectal) is not a satisfactory criterion of the mean temperature of the human body and does not therefore provide a proper basis for corrections representing its average storage of heat during any short period (five minutes) of time It might, on the other hand, be the case that energy liberated during the performance of mechanical work as the outcome of oxidation processes developed as fully at the commencement as at the end of the experiment might be stored within the body, possibly within the musculature, in some form other than heat, as, for example, in the

form of electrical energy, and therefore not discoverable by reference to changes of temperature

It is impossible to proceed with a discussion of this point until the calorimeter has been converted in some measure into a 'respiration calorimeter' such that the carbonic-acid production within it may be tested at such short intervals of time as to furnish data for curves of oxidation processes, and this I am now attempting with the assistance of Dr F A Duffield and hope to report upon at the end of another year

Leaving on one side, then, the special problem of the 'efficiency' during this initial period, I have used the data obtained after the first hour for an estimation of the maintained 'efficiency'

Estimations of the 'efficiency' of man as a machine have been found to involve two main difficulties *In the first place*, assuming that the actual external mechanical work performed at any time is accurately known, there are always present processes within the body both in parts such as the glands seemingly independent of the musculature, and even within the musculature itself, by which internal mechanical work is being performed and necessarily accompanied by a transformation of energy and a proportional sum of oxidation processes, and these processes are not constant, but vary—partly in relation to the performance of external work and partly with no relation to this factor The comparison frequently made between measured work performance and so-called 'rest' is then in reality a comparison between two imperfectly known quantities of work performance. Again, *in the second place*, it is a difficult matter to measure the mechanical work performed by movements of the body and its limbs, since work is done in those movements themselves apart from that which is done upon any mechanism to which they may be applied This second difficulty I have investigated by experiments upon the cycle without any brake and against no more than the almost negligible resistance provided by the friction of its cogs and chain and bearings Thus in separate experiments upon the 'brakeless' cycle subject E J B (age forty-five, weight 55 8 kilos, height 168 cms) gave the following results —

(1)	54 revolutions per minute,	107 kals per hour
(2)	64 ,, ,,	115 ,, ,,
(3)	74 ,, ,,	144 ,, ,,
(4)	85 ,, ,,	174 ,, ,,
(5)	96 ,, ,,	233 ,, ,,

Such results admit of approximate expression in the form $(k+x\mathrm{R}^2)$, where k is a not too satisfactory constant and R is the revolution rate Although k is not absolutely constant, it is, however, a relatively small quantity, and its variations complicate the results obtained at the lower revolution rates far more than at the higher

The thorough investigation of this question of the amount of mechanical work performed in mere movements promises to pave the way for a complete elimination of the second difficulty, but in the meantime it is more satisfactory to place in the forefront the results of experiments where the difficulty has been further avoided by the

retention of a uniform rate of movement throughout the whole series of experiments, as in the following cases —

—	Total Transformation of Energy in Kals per Hour			Current in Electrical Brakes Amperes	Mechanical Work performed on Cycle in Kals per hour	Number of Revolutions per Minute
	E J B Weight=55 8 K Height=168 cm	E S D Weight=62 0 K Height=170 cm	Dr C Weight=61 8 K Height=165 cm			
1	125	149	—	0	?	60
2	167	187	185	1	13	60
3	212	—	—	1 5	26	60
4	244	265	—	1 8	34 5	60
5	286	308	305	2 1	42 5	60

The figures given in this table for the mechanical work performed upon the cycle are taken from the results of a series of calibration experiments performed upon the cycle ergometer by Mr Crapper and his assistant, Mr Bisset, in the department of electro-technics in Sheffield University, and I have to acknowledge the great obligation which I am under for their extensive assistance In these experiments the cycle was driven by a specially convenient motor at the various speeds used by my subjects when cycling, and with a range of electrical currents in its eddy-current brake similar to that adopted in my experiments Two sets of these calibration experiments were performed, one prior to and the other later than the bulk of the calorimeter experiments, and there was a definite difference between the two probably attributable to the difference of temperature at these widely separated dates Unaware of the necessary temperature-coefficient, I have taken the figures from the later set (lower values), since this coincides better with the dates of, and temperatures prevalent at, the experiments given in the Table It should be understood, therefore, that the figures given for the mechanical work performed on the cycle are, if anything, under-estimated both from this cause and from the nature of the method used in calibration This is a point of importance, since an under-estimation of the mechanical work performed entails an under-estimation of the corresponding ‘ efficiency ’

Now, referring to lines 2 and 5 in the table, it will be seen that in the three subjects an increment in work-performance of 29 5 kals per hour (from 13 kals in line 2 to 42 5 kals in line 5) has led to the following increments in the total transformation of energy —

Increment of Mechanical Work	Increment in Total Transformation of Energy		
	E J B	E S D	Dr C
29·5	119 (286–167)	121 (308–187)	120 (305–185)

It is clear, in the first place, that the 'efficiency' of these three different persons of different ages (45, 24, 36) *and of quite different physical appearance and habits is almost the same, and in the second place that it is at least* (see remarks above) *of the magnitude of* 24 6 *per cent*

This method of proceeding by the consideration of increments of work is obviously preferable to the comparison of work and so-called 'rest,' and tends to eliminate the first difficulty described previously

In addition to these experiments, a large number of other experiments have been performed at different revolution rates, which when detailed will be found to support the conclusion arrived at as to the 'efficiency' of man as a machine

The Effect of Climate upon Health and Disease —Report of the Committee, consisting of SIR LAUDER BRUNTON (*Chairman*), MR J BARCROFT *and* LIEUT.-COLONEL SIMPSON (*Secretaries*), COLONEL SIR D BRUCE, DR G S CAMPBELL, SIR KENDAL FRANKS, PROFESSOR J G MCKENDRICK, SIR A MITCHELL, DR. PORTER, DR J L TODD, PROFESSOR SIMS WOODHEAD, *and the Heads of the Tropical Schools of Liverpool, London, and Edinburgh*

THE Committee has been in treaty with the Royal Society of Medicine, which has made certain alterations in its rules necessary for the co-option of the Committee with its Section of Balneology and Climatology

The Committee does not ask for reappointment

The Dissociation of Oxy-Hæmoglobin at High Altitudes —Report of the Committee, consisting of PROFESSOR E H STARLING (*Chairman*), MR J BARCROFT (*Secretary*), *and* MR W B HARDY

THE work of this Committee was practically completed, as it seemed, when they returned from Monte Rosa a year ago The Committee then presented an interim report accounting for the expenditure, except in so far as the outlay for apparatus was concerned As the account for this was still open, some of the apparatus being under repair, it was necessary to defer this portion of the report The amended statement of account is now presented During the past year certain control experiments have been carried out which show that the value of the work carried out in the Alps can only be duly appraised when similar experiments have been carried out during ascents from the sea-level to 1,000 feet Carlingford Mountain offers an ascent of 1,000 feet which

is very similar to that overlooked by Col d'Olen A grant of 15*l* is asked for for the purpose of carrying out experiments at Carlingford similar to those at Col d'Olen, on the same persons as far as possible.

The Ductless Glands —Report of the Committee, consisting of Professor SCHAFER (*Chairman*), Professor SWALE VINCENT (*Secretary*), Professor A B MACALLUM, Dr L E. SHORE, *and* Mrs W H. THOMPSON (*Drawn up by the Secretary*)

MRS THOMPSON has been continuing her investigations into the neck organs (thyroid, parathyroid, post-branchial body, carotid body, ventral branchial body, thymus, procoracoid, and pro-pericardial bodies) Her attention has been chiefly directed to these various structures in the frog It seems to be fully established that in the case of the American frogs which came into our hands at Winnipeg the thymus disappears or becomes invisible during the winter months The Secretary can state definitely that the same is not true of winter frogs in Edinburgh The ventral branchial body of the frog is a large and striking organ which must possess important functions Attempts have been made to extirpate the body, but these have been without success up to the present time Professor Vincent has also tried to remove the parathyroids from the frog (since these are quite separate from the thyroid), but the small size of the bodies has so far rendered the operation impossible

Mrs Thompson's results have been submitted to the Royal Society of Canada, and will probably be published in the Transactions

Drs Gardner and Mothersill have continued their experiments upon the adrenals of the dog They find, as others have done, that extirpation of one gland causes marked wasting of the animal, though this is of a temporary character They are also able to confirm the statement of some writers that after removal of one gland there is a marked compensatory hypertrophy of the other But the chief object of their experiments was to discover whether, when the animal survives for some time with a minimum of adrenal substance, there is a notable hypertrophy of the chromaphil tissues which are left behind, and in particular the abdominal chromaphil body [1] The experiments show that such hypertrophy actually occurs

Professor Vincent has found that the abdominal chromaphil body of the dog can be stained deep brown by means of bichromate of potassium even while the animal is alive This is a convenient way of extirpation of the body without surgical proceedings But in some cases the brown colour has disappeared when the animal has been allowed to survive The nature of the absorbable or soluble compound formed with the bichromate is being investigated A preliminary account of this work has been sent in to the Royal Society of Canada

[1] See Vincent, *Proc Roy. Soc* , 1910.

In conjunction with Mr A T Cameron, Professor Vincent has commenced an investigation into the chemistry of the thyroid apparatus and the rôle of iodine in the economy Some analyses of thyroids and other glands have been made, but the work has not advanced far enough to enable us to make any definite report

The Committee ask to be reappointed, with a grant of 40*l*

The Effect of Low Temperatures on Cold-blooded Animals—*Report of the Committee, consisting of* Professor SWALE VINCENT (*Chairman*), *and* Mr A T CAMERON (*Secretary*).

ON account of pressure of other work, this Committee can only make a preliminary report

Taking advantage of the exceptional temperature conditions at Winnipeg during the winter Mr Wm L Mann, B A , has carried out a series of experiments with frogs These show that exposure to a temperature of $-14°$ C for a period of somewhat over an hour is fatal, although muscular tissue is still, after thawing, sensitive to induced shocks, the heart, although it has ceased beating, is not rigid, and may recommence to beat Exposure to a temperature of $-12°$ for the same length of time is not fatal, although the animal becomes completely rigid When, however, the limbs are frozen extended, on thawing they are found to be paralysed It is probable that much smaller depressions of temperature would prove fatal if the effect could be sufficiently prolonged, a self-regulating apparatus is at present being constructed which it is hoped will give constant temperatures between $-40°$ and $+20°$, and with which a much more systematic series of observations can be attempted

The Committee request to be reappointed, with a grant of 10*l*

The Structure of Fossil Plants—*Report of the Committee, consisting of* Professor F W OLIVER (*Chairman*), Professor F E WEISS (*Secretary*), Mr E NEWELL ARBER, Dr D H SCOTT, *and* Professor A C SEWARD

THE whole of the grant of 15*l* has been devoted to the purchase of an extensive series of sections of the coal measure fossil *Sutcliffia* The interest of the specimen, which is considerable, depends upon the presence of much secondary tissue in the stem

The sections have been placed in the hands of Dr E de Fraine for description, and the results, which are of great value, will shortly be published

The Experimental Study of Heredity.—Report of the Committee, consisting of Dr FRANCIS DARWIN (*Chairman*), Mr A G TANSLEY (*Secretary*), *and* Professors BATESON *and* KEEBLE.

THE grant has been used to defray part of the cost of experiments carried on by Miss E R Saunders, Mr R P Gregory, Miss Gairdner, and Miss Sutton

The results of several years' work by Miss Saunders on the inheritance of doubling in stocks has been published in the course of the year [1] The results have shown that in the case of stocks the doubling is a character which is inherited in accordance with definite laws, and is quite unaffected by the conditions of environment In the case of certain races, it is now possible to formulate the complex scheme of gametic segregation which determines the inheritance in a given breeding Certain points concerning the way in which the inheritance of the double character is bound up with the inheritance of flower-colour require further investigation, and the work is being continued in the hope of clearing these up

The inheritance of doubling in several other genera is also now being investigated, but as these plants are mostly biennials, the results of the work of the past season will not be obtained until next year

Mr Gregory's experiments on *Primula sinensis* have been continued and extended A considerable part of the work has been devoted to the further investigation of the special inter-relations between certain genetic factors which are exhibited in this species Reciprocal crosses have shown that the gametes of both sexes may constitute series exhibiting the remarkably low types of partial 'coupling' and 'repulsion' previously reported, these low orders of partial coupling cannot therefore be explained, as at one time seemed possible, as being due to the existence of special inter-relations between the factors in the gametes of one sex only, those of the other sex being unaffected The phenomena of 'flaking' are being investigated more fully It is hoped that results of some interest may be gained from two cases of gigantism which are now under investigation, in both cases there is evidence that the nuclei differ structurally from those of the giant races previously investigated and from those of the ordinary non-giant types, in each case, too, a departure from the normal segregation appears to be indicated One of the cases is of special interest in that a sister family consisted entirely of non-giant plants, which exhibited normal segregation in F_2.

Experiments with the gynandrous variety of the common wall-flower show that this variety is recessive to the type These experiments are being continued with the assistance of Miss Gairdner, who is also making a study of the morphology of the various gynandrous forms

Tropæolum.—Miss Gairdner and Miss Sutton are continuing the experiments with *Tropæolum*, principally with a view to studying the inheritance of variegation in the leaves

[1] *Journal of Genetics*, December 1911

Clare Island.—Final Report of the Committee, consisting of Professor T. JOHNSON (*Chairman*), Mr. R LLOYD PRAEGER (*Secretary*), Professor GRENVILLE COLE, Dr. SCHARFF, *and* Mr. A. G. TANSLEY, *appointed to arrange a Botanical, Zoological, and Geological Survey of Clare Island.*

THE Committee appointed to promote a biological survey of Clare Island and neighbourhood beg leave to report that the field-work has now been completed

As notified previously, the Royal Irish Academy has undertaken the publication [1] of the results, these will be contained in a series of sixty-eight reports, of which twenty-four have been published, and eight more are at press The wide variety of subjects dealt with in the reports so far published, and the incomplete state of the work, make the presentation of an abstract of results at the present time impossible

---

The Investigation of the Jurassic Flora of Yorkshire —Report of the Committee, consisting of Professor A. C. SEWARD (*Chairman*), Mr. H. HAMSHAW THOMAS (*Secretary*), Mr. HAROLD WAGER, *and* Professor F. E. WEISS

THE work of the further investigation of this large and interesting flora is proceeding steadily During the year the Gristhorpe plant-bed has been further opened up and specimens have been obtained of the new Bennettitalean flower *Williamsoniella coronata*, fruits and seeds of *Caytonia*, fertile fronds of *Dictyophyllum rugosum* and *Eboracia lobifolia*, together with other rare and interesting fossils Some collecting at Whitby has resulted in the discovery of a Williamsonia female flower, probably a new species

A considerable amount of work has been done in the Marske Quarry, where a bed of grey shale containing some interesting plants has been discovered, a considerable number of forms has been collected there whose excellent preservation renders them suitable for the study of the cuticular structure In this bed a new fern, *Stachypteris Hallei*, was found, which has been described (by H H Thomas) in 'Proc Cambridge Phil Soc,' vol xvi, pt 7, p 610 The same locality has also yielded remains of Bennettitalean flowers The fossil flora of the Marske Quarry has now been re-examined and a paper on it will shortly be published.

The investigation of some rich plant-beds newly discovered on Rosebury Topping has been commenced This locality is of great interest as showing the extension of the plant-bearing Estuarine series towards the north-east of the Cleveland Hills Some new forms have already been discovered in this locality, where *Marattiopsis anglica* is one of the commonest species Part of the grant has been spent in the excavation of other localities in this neighbourhood, and we hope in the future to

[1] Vol xxxi. of its Proceedings.

excavate at many more places along the northern side of the Cleveland Hills, at present only the fringe of the plant-bearing strata has been touched

Though a considerable amount has been done, the work of the past year has been considerably hampered by the bad weather during the periods available for field-work.

School-books and Eyesight —Report of the Committee, consisting of Dr. G A AUDEN (*Chairman*), Mr G F. DANIELL (*Secretary*), Mr C H. BOTHAMLEY, Mr W. D. EGGAR, Professor R. A GREGORY, Mr N BISHOP HARMAN, Mr. J L HOLLAND, Professor PRIESTLEY SMITH, *and* Mr. W. T H. WALSH, *appointed to inquire into the Influence of School-books upon Eyesight.*

FROM the beginning of its investigations the Committee has had the advantage of the assistance of Dr H Eason, Professor H R Kenwood, Mr R B Lattimer, Miss Brown Smith, and Dr. Louisa Woodcock

In view of the fact that Local Education Authorities are able greatly to influence the selection of school-books, the Committee made an inquiry, on which is based the section of this report headed 'Present Practice of Local Education Authorities' At the request of the Committee Dr H Eason, Mr Bishop Harman, and Professor Priestley Smith drew up the 'Oculist Sub-Committee's Report,' to which the attention of teachers and parents is invited The latter portions of the report contain suggestions for standardising the typography of school-books, and to this portion oculists, school medical officers, directors of education, teachers, publishers, printers, and typefounders have contributed

The Present Practice of Local Education Authorities in England and Wales.

In a circular (No 596) issued by the Board of Education in 1908 the functions of the School Medical Officer are defined Under the heading of 'Arrangements for attending to the health and physical condition of school children' it is stated that he will advise the Local Education Authority with reference to improvements of the school arrangements It is further stated in the Circular that 'As regards cases of defective eyesight he will indicate such measures as can be taken to remedy or mitigate the defects by altering the position of the children in the class, or improving the lighting of the school in amount or direction; and he will call attention to the strain imposed on eyesight by the use of too small type in text-books, the teaching of very fine sewing, &c' There can be no doubt that this suggested advice has in many cases led to an improvement where certain school arrangements had been prejudicial to vision, but hitherto it has not been possible to deal effectively with the provision of satisfactory school text-books.

A circular letter was sent to the Education Authority of each county and county borough stating the objects of the Committee, and asking for information on the following points:—

(1) Whether the eyesight of the children in the schools of the Authority is tested at regular intervals;
(2) Whether advice on the care of the children's eyesight is given to school teachers;
(3) Whether the teachers instruct the children in the general care of eyesight;
(4) What regulations (if any) have been adopted for the selection of school-books and atlases (including limits of price, size of type, character of illustrations, weight, &c.), wall-maps, charts, and diagrams;
(5) Whether any definite principles or rules have been laid down by or for those who select school-books for the Authority.

Replies were received from sixty Authorities, to whom and their officers the Committee is much indebted for the information supplied.

Under the system of medical inspection now general in public elementary schools, in accordance with the day-school code, the eyesight of children of school age is tested at least twice during their school life, the test being made, with few exceptions, by means of the well-known test-cards. A few Authorities in both counties and county boroughs go further, and employ a competent oculist, either part or full time, his duty being to examine special cases and prescribe spectacles or recommend that medical or operative treatment be obtained. Some Authorities have arrangements under which spectacles according to the prescription of their oculist are supplied to the children at cost price, which is comparatively low by reason of special contracts. Arrangements are also made for free provision of spectacles in case of need, frequently with the aid of voluntary associations.

The school medical officers and ophthalmic surgeons on the occasion of their visits give advice to the teachers concerning the treatment of children with defective sight. With one or two important exceptions, however, it would seem that instruction concerning proper and improper use of the eyes in school-work has not been given to teachers. The Committee is pleased to report that, under the new regulations for the training of teachers, hygiene, including testing of eyesight, is now a compulsory subject for the Board of Education examination of training-college students.

We learn that it is not customary for teachers to give the children special instruction concerning the care of their eyes. It is stated in several instances that teaching of this kind is given incidentally in the course of the lessons on hygiene which form part of the school curriculum; but nothing more is done, and what is done amounts to very little.

Speaking generally, no definite principles or rules as to printing and other conditions of legibility have been adopted in the selection of school-books, atlases, diagrams, &c. Two or three Authorities, when drawing up their book-lists, have given considerable attention

to their possible effects on eyesight, but without formulating any definite rules. Several state that the Committee or officers responsible for the supervision of the book-supply pay attention to the type, paper, &c , several, on the other hand, inform us that the selection of books, &c , is left to the teachers

Summarising the evidence generally, it may be said that whilst effective arrangements for the detection of existing defects in the eyesight of elementary school children are general and arrangements for the supply of proper spectacles at cheap rates are not uncommon, practically no systematic attention is given to the influence of school-books upon eyesight

The replies lead us to believe that the report of the Committee will have attention from Local Education Authorities

Report of the Oculist Sub-Committee

The eye of the child is a growing eye It is immature both in structure and in function At birth the eye has a volume equal to about half that of the full-grown eye, the materials of which it is built are comparatively soft and yielding, the functional power of the visual apparatus is merely a perception of light By growth and development, rapid at first, slower later on, the eye tends progressively to acquire the dimensions and the powers of the normal completed organ

Nutrition by healthy blood, and the natural stimulus of voluntary use, are essential to this process We know by experience that in early infancy disease may arrest the growth of the eye, and that suspension of use, as when a serious ophthalmia prevents an infant for many weeks from attempting to use its eyes may check functional development to an extent which cannot afterwards be made good On the other hand, excessive efforts, due to unnatural demands on the eyesight, are apt to be injurious in the opposite direction Unfortunately there is evidence to show that the demand made on the eyesight of school children is not infrequently excessive

At the age when school life begins the visual apparatus is still immature The orbits, the eyes themselves, and the muscles and nerves which move them, have still to increase considerably in size The various brain structures concerned in vision have not only to grow but to become more complex The intricate co-ordinating mechanism which later will enable the eyes, brain, and hand to work together with minute precision, is awaiting development by training The acuteness of vision is still below the standard proper to the finished eye The refraction of the eyes is not yet fixed It is usually more or less hypermetropic, with a tendency to change in the direction of normal sight, in other words, it has not reached the ideal condition in which the eyes see distant objects without accommodative effort, but is tending towards it In short, the whole visual apparatus is still unfinished, and is therefore more liable than at a later age to injury by over-use

Over-use of the eyes is chiefly to be feared in such occupations as reading, writing, and sewing, not in viewing distant objects During near work the head is usually bent forward, and the blood-vessels of

the eyes tend to become fuller, the focus of the eyes is shortened by a muscular effort which alters the form of the crystalline lens; the visual axes, which in distant vision are nearly parallel, are held in a position of convergence, and if the work be reading they are also moved continuously from side to side It is near work, therefore, that makes the greatest demand upon the eyes, and the nearer the work the greater the strain Moreover, it is chiefly in near work that continuous mental effort is required

Children who do too much close eye-work suffer in various ways Some simply from fatigue, showing itself by inattention, mental weariness, temporary dimness of sight, or aching of the eyes and head Some from congestion of the eyes, as shown by redness, watering, and frequent blinking. A certain number, in circumstances which predispose them to the disorder, develop strabismus, or squint Some others—and these cases are perhaps the most important of all—develop progressive myopia.

Myopia, or short sight, commonly depends on undue elongation of the eyeball. It is never, or hardly ever, present at birth It is rare at five years of age It usually begins during school life, and increases more or less from year to year during the period of growth It sometimes continues to increase after growth is completed It is not necessarily, or always, associated with over-use of the eyes, either in school or elsewhere, for we see it arise after illness, we meet with it in illiterates, and we know that the predisposition to it is strongly hereditary. But it is everywhere most frequent among the most studious, and there is a mass of evidence to show that it depends very largely, both in its origin and in its progress, on over-use of the eyes in near work.

A moderate myopia which does not increase may be regarded as an innocent, though somewhat inconvenient, over-development of the eye A high myopia usually involves serious stretching and thinning of the coats of the eye, and a liability to further trouble A high myopia in a child is a very grave condition, for further deterioration always follows In connection with myopia alone, to say nothing of other eye defects, the question of school-work in relation to eyesight deserves more attention than it has hitherto received

The subject has many sides the lighting of school-rooms, the arrangement of the desks, the design and proportion of individual desks, the attitudes of the scholars, the amount of work required, are all factors of importance, but they cannot be considered here Our present effort is directed to the standardising of school-books, a very important step in the desired direction

Small print leads the young scholar to look too closely at his book He is not yet familiar with the forms of the words, and his eyesight has not yet reached its full acuteness For easy vision he must have retinal images larger than those which satisfy the trained reader To obtain these larger images he brings the book too near to his eyes, or his eyes too near the book, and this, for the reasons already given, is apt to be injurious Hence the importance of establishing certain standards of legibility for school-books, having regard to the ages of

the scholars who are required to use them, and of employing only such books as reach these standards

The importance of the matter becomes still more evident when we remember that, according to recent medical inspection, at least 10 per cent of the children in our elementary schools have serious defects of vision, and about 20 per cent errors of refraction, and see less easily and clearly, even when provided with proper glasses, than do normal-sighted children

At what age should children begin to read from books? From the hygienic point of view the later the better, and there is reason to believe that little, if anything, is lost educationally by postponing the use of books in school until the age of seven at earliest Beginners may learn to read from wall-charts, and in the general instruction of young children, teaching by word of mouth, with the help of black-boards, large printed wall-sheets, pictures, and other objects which are easily seen at a distance, is preferable from the medical standpoint, for it has the great advantage of involving no strain on the eyes.

Hygienic Requirements with which School-books should conform.

The Committee desires to acknowledge the helpful advice received from Mr J H Mason, Mr R J Davies, Mr H Fitzhenry, and Mr F Killick in connection with the technical and trade aspects of this section of its report

The factors which have been taken into consideration are: (1) The nature of the psychological process involved in reading; (2) the quality of the workmanship employed in book-production; (3) the quality of the paper on which text and illustrations are printed; (4) the character of the illustrations and the process employed for their reproduction; (5) the colour and quality of the ink used in printing the text; (6) the mode of printing, (7) the character of the type, (8) the size of the type-faces and their vertical and horizontal separation; (9) the length of the lines; (10 to 18) particular requirements of special subjects

1 *The psychology of the reading process.*—The special consideration to be here noted is that the printing should be such as will facilitate the main aim of reading—viz , the getting of the meaning of what is read The trained reader generally recognises whole words and phrases at a glance It is therefore important that the process of beginners should be made as easy as possible towards the recognition of word-wholes and phrase-wholes by the use of type suitable in character and judiciously spaced The best type for isolated letters is not necessarily the best for word-wholes, and attention must be given to the comparative legibility of letters as seen in context

2. *Workmanship* —It is possible to neutralise much of the good effect of well-selected type, paper, &c , by inefficient workmanship In all the recommendations which follow, good workmanship will be assumed.

3. *Paper.*—The paper should be without gloss Glazed paper is trying to the eyes by reason of reflections which are apt to interfere with binocular vision Pure white paper gives the greatest contrast with the ink, and therefore a paper which is white or slightly

toned towards cream-colour is to be preferred under average conditions of class-room illumination A hard-pressed paper of suitable quality should be used, as a soft paper has two defects—(1) it is readily soiled, (2) the surface is easily rubbed off and the detritus is injurious The print of one side must not show through from the other, and the printing must not affect the evenness of the surface of the other side These rules also apply to illustrations, which afford a good test of the opacity of the paper Books are occasionally bound and pressed before the ink is dried, and a faint impression of the opposite sheets causes a haze Copies with this defect should be rejected

4 *Illustrations* include (1) pictures for young readers, (2) diagrams and sketches, and (3) photographic reproductions involving considerable elaboration of detail For (1) it is important to recollect that children are only confused by elaborate or complex pictures Bold, firm treatment of a few objects is appropriate alike to their visual powers and to their understanding From this point of view line blocks from pen-and-ink drawings are preferable to half-tone blocks from photographs or from wash-drawings The pictures should be of a good size, and the printed text should not extend in narrow lines at the side In the case of (2) diagrams, it is important that the lettering should not be too small to be easily read (3) For the older scholars it is sometimes necessary to provide illustrations exhibiting details with the precision most readily obtainable by photography For the sake of obtaining effective illustrations of this kind, use is frequently made of highly glazed paper Whenever this is done it is important that such paper should be used for illustrations only, and not for the text By the use of recent methods it is possible to secure half-tone prints with good rendering of detail on matt paper (See recent British Museum publications, of which some are entirely printed on non-coated and non-shiny papers)

5 *Ink* —The ink should be a good black, and it is important to secure a proper, sufficient and even distribution of it over the whole page The use of coloured inks is strongly to be deprecated, especially the use of more than one colour on a page

6 *Mode of printing* —Ordinary text should not be printed in double columns Types should be in true alignment along the base line Hand-set type is greatly to be preferred to ordinary machine-work of the present day, indeed, much of the improvement at which this report aims will be lost if printing of the standard of hand-set type be not insisted upon The practice of printing from stereos produces quite satisfactory results, provided that the stereo is carefully made from unworn type A slight thickening of all the lines results from stereotyping, but this in no way detracts from legibility Stereos should not be used when they begin to show signs of wear

7 *Character of type* [1]—The type should be clean-cut and well-defined Condensed or compressed type should not be used, as breadth is even more important than height The contrast between the finer and the heavier strokes should not be great, for hair-strokes

[1] For explanation of technical terms, see Appendix.

are difficult to see. On the other hand, a very heavy-faced type suffers in legibility through diminution of the white inter-spaces, as, for example, when the space in the upper half of the *e* is reduced to a white dot. In an ideal type the whites and blacks are well balanced in each letter, and it is easy to discriminate between *e*, *c*, and *o*, between *i* and *l*, and between *h* and *k*; and to recognise *m*, *nn*, *nu*, *nv*, *w*, *in*. The general form of the letters should be broad and square rather than elongated vertically, thus the letter *o* should approach the circular shape. Legibility is not increased by adding to the height of a letter without adding to its width. There should be a lateral shoulder on every type, so that each letter is distinct. Long serifs should be avoided, and any extension sideways which forms or suggests a continuous line along the top or bottom is detrimental.

The upper half of a word or letter is usually more important for perception than is the lower half, because the upper half of most letters has a more distinctive shape than the lower. In some recent type-faces the designers have accordingly shortened the letters below the line, and lengthened those above—thus the *p* is shortened and the *h* lengthened, at the same time the upper parts of the *r* have been raised. It is too early to pass judgment on the results, and more experiment is desirable. It is possible that legibility would be increased by giving more distinctive character to the *lower* half of a larger proportion of letters.

With reference to the question of 'modern-face' *versus* 'old-face' design for type, the Committee is not prepared to advise the use of either to the exclusion of the other, good and bad varieties of both styles being at present in use. It is claimed for the 'modern face' that the letters are more legible, and it may be conceded that failure to provide the minimum height of the short letters is more frequent in 'old face.' Hence the letters of the 'modern face' are usually more legible in the case of sizes below twelve-point. The advocates of the 'old face' contend that the 'modern face' letters remain isolated, whereas the letters of the 'old face' flow more naturally into words; thus the form of the word and its meaning are apprehended smoothly. It is also claimed that the basic design of the 'old face' is of higher æsthetic merit. The Committee insists on the importance of the minimum height and breadth for the small letters (vide columns 2 and 3 of the table), and if this be secured, leaves the decision between the 'modern face' and 'old face' to individual judgment helped by the criteria provided in various paragraphs of this report.

Italics, being less easy to read than ordinary type of the same size, should be used sparingly.

8. *The size of type-faces and their vertical and horizontal separation.*—The size of the type-face is the most important factor in the influence of books upon vision. Legibility depends mainly on the height and breadth of the short letters, for the larger the type the further from the eyes can it be read with ease, and it is of the first importance to induce the young reader to keep a sufficient distance between eyes and book. Children under seven years old should be able to lean back in their seats and read from the book propped up on

the far side of the desk (As a rule books should not be too large or heavy to be held in the hand.) The appended typographical table shows the minimum requirements, in the opinion of the Committee, for the various ages given; the dimensions being given in a form which can be understood and utilised by readers unacquainted with the technical terms used by printers

Typographical Table.

Age of Reader	Minimum Height of Face of Short Letters	Minimum Length of Alphabet of Small Letters	Minimum Interlinear Space	Maximum No of Lines per Vertical 100 mm or 4 inches	Maximum Length or Measure of Line
Under 7 yrs.	3.5 mm	96 mm or 272 pt.	5 mm or 14 pt	12	
7 to 8 yrs .	2.5 mm	72 mm or 204 pt	3.6 mm or 10 pt.	16	100 mm. or 4 in
8 to 9 yrs. .	2.0 mm	55 mm or 156 pt	2 mm or 6 pt	20	93 mm. or $3\frac{2}{3}$ in.
9 to 12 yrs. .	1.8 mm.	50 mm or 143 pt	2 mm. or 6 pt	22	93 mm. or $3\frac{2}{3}$ in
Over 12 yrs	1.58 mm or $\frac{1}{16}$ inch	47 mm or 133 pt	1.8 mm or 5 pt	24	93 mm or $3\frac{2}{3}$ in.

1 inch = 25.4 mm 1 point = $\frac{1}{72}$ inch = 0.353 mm

Specimens of printed matter conforming with the above table will be found in a Supplement The four-inch steel rule 'Chesterman 410 D' is convenient for these measures.

The sizes and spacing of the type suggested for age eight to nine years may be adopted for older readers, including practised adults.

The column giving the minimum length of the alphabet of the small letters (*i e* , not capitals) affords a measure of the breadth of the types Strictly speaking, this cannot be measured by the reader of a book A sufficiently good estimate can be made when it is recollected that there are twenty-six letters in the alphabet, and accordingly a word of thirteen letters should not fall short, to a material extent, of half the lengths stated in the third column Thus the word 'typographical' should measure nearly 25 mm in type adopted for readers under twelve (This may be tested in the examples given in the Supplement) A rough rule may be given thus: The number of letters per running inch or 25 mm should not on the average exceed—

6 or 7	letters	for	readers under	7 years.
8 or 9	,,	,,	from 7 to 8	,,
11 or 12	,,	,,	,, 8 to 9	,,
13	,,	,,	,, 9 to 12	,,
13 or 14	,,	,,	over 12	,,

By 'interlinear space' is meant the vertical distance between the bottom of a short letter and the top of a short letter in the next line below This space between the lines should vary in proportion to the size of the type Too little space is a source of fatigue in reading,

for it involves difficulty in passing from the end of a line to the beginning of the line below. Very wide space, on the other hand, has no advantage as regards legibility, and involves waste of paper and undesirable increase in the size of the book. Columns 4 and 5 of the table indicate a suitable proportion.

9. *The length of the line* also is a matter of importance. Other things being equal, the longer the line the greater the excursions of the eyes and the greater the difficulty in passing from one line to the next. Very short lines, on the other hand, demand too frequent a change of direction in the movement of the eyes. The use of lines longer than the maxima given in the last column of the table is sure to cause fatigue to a considerable proportion of readers.

Approximate uniformity in length is desirable, but not absolute uniformity. It is doubtful whether the power of fairly rapid intelligent reading can be attained without the *unconscious* performance of the swing from near the end of each line to near the beginning of the next. This swing may be compared with the motion of an oarsman's body between the strokes. A slight indentation in the lines helps the reader, but a large one hinders the acquisition of a good habit of swing. Children of eight years old should not have their reading confined to very short paragraphs, as the habit of swing has been found well established in good readers of between nine and eleven years of age. In other words, these readers made the necessary eye-movements without conscious effort and with great regularity.

U n u s u a l s e p a r a t i o n of letters should be avoided. For beginners, lines should not end in the middle of a word, the whole word should be carried to the next line and not be hyphened. The admission in the table of a four-inch line for the large type is a concession intended to meet the difficulty of securing an even set of the letters in a line of shorter measure.

Good margins are restful to the eye, and are well worth their slight cost.

10. *Particular Requirements of Special Subjects. Bibles, Prayer-books, and Hymn-books.*—It is to be regretted that these books are so frequently printed in type which is injurious on account of its small size. It is desirable that the standard given in the table should not be lowered with respect to these important books, which are frequently used under poor conditions as regards illumination.

11. *Books for Evening Work.*—The unfavourable conditions resulting from artificial illumination and fatigue of the learners make it highly desirable that the rules 'from age twelve' should be maintained for books to be used in all evening classes, or for home-work, even for adults.

12. *Exercises, Sets of Examples, and Questions.*—These are the most important parts of a school-book, so far as influence upon vision is concerned, and the rules for the printing of them should on no account be less stringent than those applied to the rest of the book. The same rules should be applied to test-cards. The use of hektographing or other multiplying processes is increasing in schools. Care should be taken to secure clear and legible copies.

13. *The Types for Mathematical Symbols* should correspond with, or be larger than, the sizes of type recommended for the various ages. It is important that the smaller symbols should not be too fine, and it is advisable to employ the 'heavy' type for fractions which is described by typefounders as 'heavy fractions.' For children under twelve years no fractions should be employed less than 3·5 mm. in height of face, thus in $\frac{3}{4}$ the distance from the top of the 3 to the bottom of the 4 should not be less than 3·5 mm. For pupils over twelve the minimum face height for fractions should be 3 mm. If heavy fractions be not used, these heights should be increased to 4 and 3·5 mm. respectively. It should be easy to discriminate between the numerals 3, 6, 8 and 9.

14. *Squared Paper.*—Use of squared paper should be restricted to work for which it is really required. If this be done, and paper with rulings not less than one-tenth inch apart be used, there will be little danger to vision. The use of millimetre paper should be restricted to students over fourteen, and be only used by them in a good light—on exceptional occasions.

15. *Atlases.*—It does not appear possible to avoid some use in atlases of type which is below the desirable standard of size, and the care which should be exercised by teachers in regard to the children's eyesight needs to be specially emphasised in this connection. Their use should be avoided when the illumination is below normal—the less they are used for home-work the better. Location by reference lines should be taught from the beginning, and children should not be allowed to hunt for a name in an undirected fashion, as they may thus have to read fifty names in finding the one sought. Atlases intended for use by children under nine should have no type smaller than ten-point, with minimum height of 1·6 mm. or one-sixteenth inch for the short letters. No school atlas should be printed with type smaller than eight-point, with minimum height of 1·2 mm. for the short letters. The type should be extended, italics should not be used more than is necessary, and should not have fine hair-lines. Type of display character may be used with advantage.

It is not necessary that every map should be coloured. (It has already been pointed out that colour decreases legibility.) In the case of beginners, the colour helps the appreciation of area, but for this purpose the colouring should be pale, and few names inserted. For the portrayal of relief, the practice of block-shading the contours is better than heavy black hill-shading by hachures. Maps should be duplicated where it is necessary (*e.g.*, Switzerland) to exhibit great variation of contour together with several place-names. In general it is better to multiply maps than to put much detail into one.

If a system of inserting the names of every town of a certain population be adopted, the result is certain to be overcrowding of those portions of the maps which represent highly-populated countries. It would be better to avoid this overcrowding, even at some sacrifice of systematic uniformity. Modern methods in the teaching of geography are reducing the hunting for place-names, and thereby diminishing eye-strain. This advantage will be more general when

the supply of orographical maps to public elementary schools is increased The reading of Ordnance Survey sheets by the older pupils is not objected to, provided they are used in good daylight

16. *Music* —For the tonic sol-fa notation the minimum height of the short letters should be (*a*) for music, 2 mm.; (*b*) for words, 1 5 mm. Staff music is often produced by lithography, in which all gradations of size and shape are possible Care in printing is needed, so as to secure well-defined stave-lines and tails Advantage should be taken of the elasticity in the length assigned to different bars in the lithographed music, so as to avoid compression of complicated passages For beginners music of the size of the 'Giant Note' is recommended For others, the stave-lines should not be less than 1 75 mm. apart (see specimen of ruby, or five-point, in the Supplement) The ruled paper for music-writing should have lines not less than 2 mm apart

17 *Greek* —Greek type is troublesome to beginners by reason of its unfamiliarity and of the difficulty of synthetising accents and letters into word-wholes The correct Porson type has a line of uniform thickness Such type affords easy discrimination of individual letters, and is legible in mathematical formulæ, even when small sizes are used. For reading, it is recommended that no type smaller than twelve-point be used for beginners, or eleven-point for experienced readers The variety of Greek type which employs fine hair-lines should be entirely abandoned Uncial Greek may be recommended as being easy to read (see Supplement)

18 *German* —The older styles of German type are less easily legible partly on account of the ill-placed hair-lines at the top of the letters Recent forms of the black letter used in German books are improved in this respect, but since Roman type is being used largely even for literary works in Germany, the use in our schools of the less legible German types may be reduced with some gain to the security of eyesight.

Conclusion

The Committee observes in conclusion that —

(1) The existence of a very serious amount of visual defect among children of school age is established as a result of official inspection Some portion of this defect is preventable by greater care in the selection of books

(2) It is desirable that a standard of book-production should be established, and that the publication of books below standard should cease.

(3) It appears possible that the adoption by local education authorities of a common standard would render unprofitable the publication of books which failed to reach such standard.

(4) It is hoped that this report may assist the responsible authorities in the work of determining the standard of book-production requisite for the protection of the eyesight of children so far as it is influenced by the books which the children are compelled to read in school.

1912.

APPENDIX.

Note on Technical Terms used in this Report.

Type-body, type-face, lateral shoulder, large-face.—The letters are cast on a 'type-body', the part of the type which actually leaves its impress is the 'face'. When the face is nearly as large as the body will carry, the type is 'large-face.' The space on the upper surface of the body on each side of the face is the lateral 'shoulder.' All one reads is the impress of the faces of the types.

Serif.—A type in which each letter had only its bare necessary features would be 'without serif,' the serifs being the terminals of the letters. If of proper design, the serifs guide the eye from letter to letter and give a balanced effect. In some styles the serifs take the form of purposeless ornament, which is undesirable in books which are intended for continuous reading.

In *condensed* or *compressed* type the bodies are narrow, so that the letters are narrow and close together. Column 3 of the typographical table excludes such type.

Old face and *modern face* refer to styles of type. In the specimens in the Supplement the faults of the more extreme varieties of each have been avoided.

Heavy type, heavy fractions refer to type of which the lines are thick.

Point is a unit of measurement=1/72 of an inch. Thus an eighteen-point type has a body one-quarter inch high. The face may be of any size smaller than the body.

Solid and *leaded.*—If the types of consecutive lines are set with no vertical interval between the bodies, the type is 'solid.' When there is a vertical interval, say of a thirty-sixth of an inch, the type is 'two-point leaded.' A large-face type of ten-point body with two-point leading will produce about the same vertical space between the short letters as a small-face type of twelve-point body printed solid.

An *indentation* occurs in a line where the print does not extend to the same length as in neighbouring lines.

SUPPLEMENT.

SPECIMENS OF TYPE.

THE Committee draws attention to the fact that there is considerable variation in the size of the faces of the various types coming under the same rating in point body, or bearing the same trade description. The following specimens afford satisfactory examples of existing types which conform with the dimensional rules proposed by the Committee. For age-periods 'seven to eight' and 'over twelve' the smallest examples show the smallest sizes which the Committee regards as permissible.

The specimens may usefully be compared by measurement with the specifications in the Typographical Table.

No 1

UNDER SEVEN.

This type may be used for books to
be read by children under seven.
years The letters are larger than the
minimum in the typographical table.
Printed from type known as Thirty
Point Caslon Old Face lent by Messrs.
H. W. Caslon & Co. Ltd., 82 & 83
Chiswell Street, London, E.C.

No. 2.

UNDER SEVEN.

This type may be used for books to be read by children under seven. The letters are larger than the minimum given in the typographical table. Printed from 24 Point Lining Old Style No. 5, lent by Messrs. Stephenson, Blake & Co., 33 Aldersgate St., London.

No 3.

UNDER SEVEN.

The letters of this type are slightly larger than the minimum given in the typographical table. Printed from 24 Point Old Style Antique, No. 7, lent by Messrs Miller and Richard, Water Lane, London, E.C., and Nicolson Street, Edinburgh.

No. 4. **AGE SEVEN TO EIGHT.**

The letters of this type are larger than the minimum given in the typographical table. Printed from 18 Point Old Style Antique, No. 7, lent by Messrs Miller and Richard

No. 5. AGE SEVEN TO EIGHT.

The letters of this type are larger than the minimum given in the typographical table. Printed from 18 Point, No. 11, lent by Miller and Richard.

No. 6. AGE SEVEN TO EIGHT

This type may be used for books to be read by children from seven to eight years old. The letters are larger than the minimum given in the typographical table. Printed from Eighteen Point Haddon Old Style, No. 1, lent by Messrs. John Haddon & Co., Salisbury Square, E.C.

No. 7. AGE SEVEN TO EIGHT

This type may be used for books to be read by children from seven to eight years old. The letters are larger than the minimum given in the typographical table. Printed from Eighteen Point Haddon Modern, lent by Messrs. John Haddon & Co., Salisbury Square, E.C.

No. 8. AGE EIGHT TO NINE

This type is suitable in size for books to be read by children from eight to nine years old. The size of the letters is slightly larger than the smallest given in the typographical table. Printed from Twelve Point Haddon Modern with 2 point Leading, lent by Messrs. John Haddon & Co.

No. 9. AGE EIGHT TO NINE.

This type is suitable in size for books to be read by children from eight to nine years old. The size of the letters is slightly larger than the minimum given in the typographical table. Printed from Twelve Point Lining Cambridge Series, with 2 point Leading, lent by Messrs. R. H. Stevens and Co., 89 Southwark Street, London, S.E.

No. 10. AGE NINE TO TWELVE.

This type is suitable in size for books intended for readers over nine years old. The size of the letters is slightly larger than the smallest given in the typographical table. Printed from Eleven Point Haddon Modern with 2 point Leading

No. 11. AGE NINE TO TWELVE.

This type is the smallest suitable in size for books intended for readers over nine years old. The size of the letters is equal to the minimum given in the typographical table. Printed from 12 Point Old Style, No. 4, with 1 Point leading, lent by Messrs. Miller & Richard.

No. 12. AGE NINE TO TWELVE.

This type is the smallest suitable in size for books intended for readers over nine years old. The size of the letters is equal to the minimum given in the typographical table. Printed from 12 Point, Old No. 2, with 1 Point leading, lent by Messrs. Miller & Richard.

No. 13. OVER TWELVE

This type is suitable in size for books intended for practised readers over twelve years old. The size of the letters is in conformity with the smallest dimensions given in the typographical table. Printed from Ten Point Haddon Modern with 2 point Leading, lent by Messrs John Haddon & Co

No. 14 OVER TWELVE.

This type is the smallest suitable in size for books intended for practised readers over twelve years old. The size of the letters is in conformity with the dimensions given in the typographical table. Printed from 11 Point Old Style, No. 4, with 1 Point leading, lent by Messrs Miller and Richard.

No 15 OVER TWELVE.

This type is the smallest suitable in size for books intended for practised readers over twelve years old. The size of the letters is in agreement with the requirements specified in the typographical table. Printed from Ten Point Large Face with 2 Point Leading, lent by Messrs. R. H Stevens & Co.

No. 16.

Haddon Heavy Fractions.

18 Point	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
12 Point	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
10 Point	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$

Printed from type lent by Messrs. John Haddon & Co.

No. 17.

ANTIQUE FRACTIONS.

18 Point	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{6}$	$\frac{7}{8}$
12 Point	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{6}$	$\frac{7}{8}$
10 Point	$\frac{1}{2}\frac{7}{8}$	$\frac{3}{4}\frac{9}{1}$	$\frac{5}{6}\frac{0}{9}$	$\frac{6}{8}\frac{6}{8}$

Printed from Old Style Antique, No 7, lent by Messrs. Miller & Richard.

No 18.

FRACTIONS.

Figures with separating Rule.

$\frac{\text{10 Point}}{\text{10 Point}}$	$\frac{3}{4}$	$\frac{5}{6}$	$\frac{7}{8}$
$\frac{\text{8 Point}}{\text{8 Point}}$	$\frac{3}{4}$	$\frac{5}{6}$	$\frac{7}{8}$
$\frac{\text{6 Point}}{\text{6 Point}}$	$\frac{3}{4}$	$\frac{5}{6}$	$\frac{7}{8}$

No. 19.

12 POINT PORSON GREEK.

ΔΙΟΔΕΥΣΑΝΤΕΣ δὲ τὴν Ἀμφίπολιν καὶ Ἀπολλωνίαν, ἦλθον εἰς Θεσσαλονίκην, ὅπου ἦν ἡ συναγωγὴ τῶν Ἰουδαίων, κατὰ δὲ τὸ εἰωθὸς τῷ Παύλῳ εἰσῆλθε πρὸς,

No. 20.

UNCIAL GREEK ON LONG PRIMER BODY

ΠΟΙΗϹΟΝ ΗΜῖΝ ΘΕΟΥϹ Οἳ ΠΡΟΠΟΡΕΥϹΟΝΤΑΙ ΗΜῶΝ Ὁ ΓᾺΡ ΜΩΥϹΗϹ ΟὖΤΟϹ, ὋϹ ἘΞΗΓΑΓΕΝ ΗΜᾶϹ ἘΚ ΓΗϹ ΑἸΓΥΠΤΟΥ, ΟΥΚ ΟἾ Ὁ ΘΕῸϹ ΤῶΝ ΠΑΤΕΡΩΝ ϹΟΥ, Ὁ ΘΕῸϹ ἈΒΡΑᾺΜ ΚΑῚ ἸϹΑᾺΚ ΔΗΜΑ ΤῶΝ ΠΟΔῶΝ ϹΟΥ

No 21.

TONIC SOL-FA MUSIC.

(The smallest size suitable for school use)

The above Specimens are printed from Type lent by Messrs. R. H. STEVENS & Co.

No. 22. SPECIMEN OF RUBY MUSIC BY R. H. STEVENS & Co.

Correspondence relating to the subjects dealt with in this report should be addressed to the Hon. Secretary of the Eyesight Committee. Intending purchasers should apply to the

ASSISTANT SECRETARY,
BRITISH ASSOCIATION,
BURLINGTON HOUSE,
LONDON, W.

The Curricula and Educational Organisation of Industrial and Poor-Law Schools.—Report of the Committee, consisting of Mr. W. D. EGGAR (*Chairman*), Mrs. W. N. SHAW (*Secretary*), Professor R. A. GREGORY, Mr. J. L. HOLLAND, Dr. C. W. KIMMINS, *and* Mr. J. G. LEGGE, *appointed to inquire thereinto, with special reference to Day Industrial Schools.*

PRELIMINARY STATEMENT OF THE VARIOUS TYPES OF SCHOOLS AT PRESENT EXISTING IN THIS COUNTRY.

IN the following remarks no notice is taken of the Secondary schools, or of those day and residential Preparatory schools by which they are fed, and which give only the earlier stages of a full secondary education. Their official inspection was first provided for under the Board of Education Act of 1899, section 3; it has not hitherto been made compulsory upon every such school.

The education of the remainder, constituting the vast majority, of the nation's children is carried on in schools exhibiting a great variety of type, and subject to very different conditions of inspection and control.

(1) *Public Elementary Schools.*—These are controlled by the Board of Education on the one hand and the Local Education Authorities on the other, and are inspected and reported on both by his Majesty's Inspectors and by those of the Authorities. They are formally defined in the Education Act of 1870, section 7, and also (to meet the case of certain Public Elementary Schools carried on in connection with Residential institutions) section 15 of the Education Act, 1892. These schools are all regulated by the Board's annual Code of Regulations. *Higher Elementary Schools* are a development of these, and were first established by a Minute of 1900; their regulations are embodied in the same Code.

(2) *Certified Efficient Schools.*—These are officially defined in the Elementary Education Act of 1876, section 48. They comprise any elementary school other than the above which is open to the Board's Inspectors and is certified by the Board to be an efficient school. Many of these are institutions included under one or other of the succeeding types.

(3) *Reformatory and Industrial Schools* have their latest official definition in the Children Act, 1908, section 44; industrial training, clothing and lodging are provided in each case, in addition to the teaching. These schools are controlled and inspected by a staff of officers directed by the Home Office; they are also visited, in some cases at least, by Inspectors of the Local Authorities. To the Reformatory may be sent convicted offenders of from twelve to sixteen years of age, in lieu of imprisonment. The Industrial School receives, at the instance of a Court of Summary Jurisdiction, younger offenders, neglected children, and children of criminal or worthless parents. The *Day Industrial Schools*, first sanctioned under section 16 of the Elementary Education Act of 1876, receive children committed under a magistrate's

warrant for neglecting to attend school, for begging, for petty thefts, and for being beyond control, others are admitted as voluntary cases by the local authorities The *Short-term Industrial Schools* exist in a few areas to deal mainly with habitual truancy.

(4) *Prison Classes* —Here the instruction is of an elementary character, though the prisoners are usually above the ordinary school age. Teaching is given in local prisons, convict prisons, Borstal institutions, and State inebriate reformatories, it is reported on to the Home Office, through the Prison Commissioners, by the Chaplain-Inspector.

(5) *Schools for Children under the control of the Poor-Law Authorities* —Children of families in receipt of 'outdoor' relief attend the Public Elementary school and are controlled and inspected in the same way as its other scholars It has also been the policy of the Local Government Board of late years to encourage sending 'indoor' children to the same schools, but about half of these are educated under the control of the Guardians in the district workhouse or some other form of Poor-Law school, a few in infirmaries receive such instruction as they are fit for from special teachers, and some others receive technical or industrial instruction solely The whole Poor-Law system is controlled and inspected by the officers of the Local Government Board, but by arrangement with the Board of Education the inspectors of the latter report upon the education of the children

(6) *Schools whose special character depends on the physical or mental health of their children* —(*a*) Schools for the Blind, (*b*) for the Deaf and Dumb, (*c*) for the Epileptic; (*d*) for the Physically Defective; (*e*) for the Mentally Defective; (*f*) a school for the Phthisical; and (*g*) a few open-air schools So far as public provision is concerned, (*a*) and (*b*) were established by the Elementary Education (Blind and Deaf Children) Act of 1893, and (*c*) and (*d*) by the Elementary Education (Defective and Epileptic Children) Act of 1899; the former Act is compulsory in its operation, the latter permissive, they are subject to the Board's special regulations, and are reported on by its officers, some are also visited by the Local Inspectors In this type of school the medical aspect of inspection is naturally considered as important as the educational

Some of the charitable and other institutions included here are certified and inspected by the Board of Education, but there are also cases where there is no outside educational control, and where such inspection as obtains is conducted on behalf of the societies, or even individuals, to which they belong

(7) *Institutions under various Societies for the care of Waifs and of Orphans* —Some of these are recognised as public elementary schools under section 15 of the Education Act, 1902, and are inspected by the Board of Education In other cases the controlling society may make its own arrangements for inspection: others, again, have no educational inspection by an independent authority.

(8) *Naval Schools and Training Ships for the Navy* —These are controlled and inspected under the Director of Naval Education as well as by the Board of Education.

(9) *Army Schools* for the children of non-commissioned officers and men; these are under the Director of Military Education.

(10) *Training Ships for the Mercantile Marine*—These (save reformatory and industrial-school ships) are usually certified and inspected by the Board of Education, while they are also answerable to any body of Guardians from whom they may have received boys In certain cases inspection in seamanship is conducted by the Admiral-Superintendent of the Naval Reserves Reformatory and industrial-school ships are inspected by officers appointed by the Home Office, and also in seamanship by the Admiral-Superintendent of the Naval Reserves

(11) *Private-Adventure Elementary Schools*—These are very few and of small size, they are usually survivals which have been recognised by the local authority

(12) *The Lunatic, Idiot, and Imbecile Asylums* contain a number of children who are not educable in the ordinary sense of the term They are controlled and inspected by the Commissioners in Lunacy

(13) To complete the review, mention must be made of children who ought to be but are not found on the roll of one or other of the above, such as children sick at home, others who are at home only because they have evaded the eye of the school attendance officer, and others, again, like the caravan and canal-boat children, who are difficult to fix because their home itself is migratory, but whose education is governed by section 118 of the Children Act, 1908, and the Canal Boats Act of 1877

REPORT

This Report is concerned with the schools of paragraphs 5 and 7—that is, with institutions which receive children of the same class as those in Industrial Schools and with children under the Poor Law

There was some difficulty in finding the schools, but ultimately lists were obtained from the Local Government Board, the Board of Education, and the Charity Organisation Society The remainder were taken from 'The Charity Digest,' and from the 'Classified List of Child-Saving Institutions' published by the Reformatory and Refuge Union As regards the Poor-Law schools it was stated by the Local Government Board that it would be extremely difficult to give a list of the various establishments in which indoor pauper children are housed; the printed list supplied by them is of 'Schools and Institutions certified by the Poor Law Board and the Local Government Board under the statute 25 and 26 Vict, c 43' Circulars with a covering letter (see Appendix) were sent to 541 institutions In each case a stamped directed envelope was enclosed for reply.

Of these 541 circulars 335 came back It was evident from some of the answers that many of the schools were suspicious of the motive of the inquiry. One gentleman wrote: 'I refuse to acknowledge the right of this or of any other Society to ask these questions, or to interfere in any way with schools charitable or otherwise, to the maintenance of which it does not contribute' Two ladies refused information in

less curt terms. A considerable number of schools misunderstood the meaning of 'curriculum' and 'time-table.' These misunderstandings necessitated the writing of many additional letters of explanation, the replies to which were in the majority of cases satisfactory.

Homes and Schools.

As many of the institutions approached made use of the elementary day schools of the parishes in which they were situated, a distinction has been drawn between *Homes* in which the children are merely boarded and fed and *Schools* which in addition provide for education in their own buildings

The returns include:—Dead letters, 8, Schools not included in inquiry, 10; Schools reported closed, 13; Homes answering, 243; Schools answering, 92; leaving 175 circulars to which no answers were received.

Of the 175 not answering, 148 were identified and 27 could not be traced, probably owing to the misfortune that one sheet of the list of schools supplied by the C O S had been mislaid Sixty-eight of the 148 which were identified are schools certified by the Local Government Board.

Homes for Children under the Control of the Poor Law Authorities

In 1906 a Departmental Committee was appointed by the Board of Education to report upon the 'Educational work in Poor Law schools and in the 23 schools certified under the Poor Law (Certified Schools) Act, 1862, which are inspected by the Board of Education.' It appears from the Report that there are sixty thousand children under the charge of the Poor Law. The schools under inspection by the Board of Education include:—Workhouse schools, 15; District schools, 7; Metropolitan Asylums Board schools, 6, Separate schools, 41; and Certified schools, 23, in connection with not more than 108 Unions There are in England and Wales over 600 Unions; 269 schools are certified for the reception of Poor-Law children 'Of these 23 are on the list of schools inspected by the Board of Education at the request of the Local Government Board; 20 others are inspected because they are Public Elementary schools under section 15 of the Education Act, 1893, and 1 under the Elementary Education (Defective and Epileptic Children) Act, 1899. So far as we are aware, the remaining 208 are not subject to any educational inspection at all' (Departmental Report, 1908)

Scope of the Inquiry.

The Committee have assumed that it is not necessary to inquire into the conditions of schools which are under official recognition—that is, into schools under the inspection of (1) the Board of Education; (2) Local Education Authorities, as these are inspected and reported on by his Majesty's Inspectors and by those of the Authorities.

Schools.

Answers were received from the following schools:—Boys, 25; Girls, 38; Mixed, 29.

Referring to the circular in the Appendix the answers to the questions may be tabulated thus —

(2) The majority of the schools are apparently under private management. Seven state that they are under a Board of Governors.

(3) Forty of the schools take fees for all or some of the children, 52 are entirely free.

(4) The schools are of various sizes—from a Roman Catholic school of 450 to a Waifs and Strays' school of 12. So far as the numbers are given the uncertified schools appear to provide accommodation for:—4,413 Boys; 3,747 Girls, 895 Mixed, the certified schools provide accommodation for:—3,348 Boys, 2,391 Girls, 1,878 Mixed, making totals of 7,761 Boys, 6,138 Girls, 2,773 Mixed—that is, a sum total of 16,672 children

(5) The information about the Teaching Staffs varies and is difficult to tabulate The following table is approximately correct:—

15 Schools give no information about the teaching staff
22 have no certificated teachers, all are unqualified
23 have a mixed staff
15 have a mixed staff stated to be approved by the Board of Education
15 have no unqualified teachers, all are certificated
2 have a mixed staff including graduates and others with higher qualifications

(6) Twenty-four have visiting teachers for technical work and drill, with the exception of drill-sergeants and band-masters very few of these are trained teachers They include tailors and shoemakers and other teachers of trades whose qualification is their own experience

(7) The buildings of twenty-two of the schools are inspected by the Local Government Board The replies as regards educational inspection may be tabulated thus:—

8 give no information as to inspection or examination
3 are neither inspected nor examined.
4 are inspected by members of their committees,
2 by local clergymen,
5 by local elementary schoolmasters,
7 by the Children's Aid Association, Waifs and Strays Committee, or by the Reformatory Union,
9 by Diocesan Inspectors as far as Scripture only is concerned,
3 by the Admiralty,
2 occasionally, by request, by the Board of Education,
2 send pupils in for the University Local Examinations,
2 are examined by Local Authorities,
40 by the Board of Education.

(8) A considerable number of the schools omit to answer the question both as regards the curriculum and time-table:—

18 enclose written time-tables, some of which are elaborate and apparently excellent

34 enclose printed reports and refer to these for the curriculum and time-table, but the majority of the reports deal generally with the wants and rules of the institutions and say little about the education of the children.

11 state that the education given 'corresponds to that in ordinary elementary schools'

1 gives 'a sound English education'

1 gives 'a sound education not too advanced'

The school subjects taught in the majority of the schools include the three R's, with some geography and history One school alone states the history to consist of the history of Parliament and how we are governed. A few others give the special periods of history which are being taught

(9) The number of classrooms varies:—

12 make no mention of classrooms

9 have each one classroom the number of children in these schools varies from 18 to 104, and this last has a division in the classroom

7 have two classrooms the number of children in these schools varies from 16 to 90.

1 has nine classrooms this school has 303 children

1 has thirteen classrooms this school has 321 children

(10) Three of the schools have laboratories for the teaching of science, one of which is reported to be 'not adequately fitted for lack of funds' The science lessons appear to take the form of object lessons, Nature study, and lantern lectures. One school said to be interested in science asks where to obtain lantern slides

(11) The occupations of the children out of school hours are very various In some cases they include walks, gardening, and games, in many they are housework and sewing

Three or four schools state that they have libraries and put reading amongst their recreations

Twenty schools make no mention of technical training.

Thirty-one train girls for domestic service, but it is only in cooking and in one or two cases in nursing, that the instruction is given by qualfied teachers One school is admirably fitted, but for the rest domestic training appears to consist in doing the work of the house under the supervision of untrained matrons.

For the boys the technical training is much better organised, and in some cases visiting teachers are engaged for it One school has a list of thirteen trades, and most schools appear to give alternatives to the boys. In a few the boys assist with the housework and gardening. There is one small school where the whole number of thirty-two boys are engaged in wood-chopping. It has no inspection from outside and 'would welcome a visit.'

Homes.

The 243 Homes include —43 for Boys, 110 for Girls; 89 Mixed Seventy-seven of these institutions provide accommodation for 1,043 Boys; 1,859 Girls; 131 Mixed; a total of 3,033 children

A large number of blank forms were returned, and the information the Committee obtained had in these cases to be extracted from enclosed printed forms or from printed lists of schools:—

38 of the homes sent printed reports.
5 returned the forms with the names of the schools, but gave no further information One lady states that she 'does not desire to fill up the papers,' another that she is 'unable to do what you desire'

The homes are not all free, thirty-six receive fees from Boards of Guardians

As the children attend the ordinary Elementary schools the educational work is under inspection by the Board of Education —

38 of the homes are inspected by the Local Government Board
47 are Church of England Homes for Waifs and Strays, and are inspected by their own Committees
5 are not inspected at all
6 are inspected by the Rescue Society
11 are reported closed
73 say nothing about inspection
40 are under private inspection
18 state in writing their willingness to be visited
2 decline to be visited.

Technical Work

There was no information given as to the details of technical training —

86 of the homes train girls for domestic service
3 train boys for distinct trades
A few of the homes send children to Canada

There is no evidence from the reports or otherwise that the girls are trained for service by qualified teachers; they assist in the housework of the homes

General Remarks

The main conclusion arrived at by the Committee is that while orphanages for children of distinct classes of workers appear to be doing admirable work, and in particular the Roman Catholic schools of certain localities are excellent, yet many institutions for poorer children provide a very monotonous education even when the children go out to the elementary schools

In most cases there is no evidence that the education given prepares the children for after life The teachers are to a great extent untrained, especially in technical work, and it is doubtful if the technical work taught is of a standard to be useful in any trade

In particular the training of girls for domestic service appears to be in reality a plea for no training at all. It is not likely that all the girls from 86 out of 110 homes are suitable for domestic service, and no alternative is offered to them. The distaste of older girls for domestic service is probably in a large part due to their employment in Homes in housework when other children are at play. Training for domestic service is in fact only another name for the employment of children of school age as domestic servants.

In the case of boys things are a little better, but there is one school where the boys are employed wholly in wood-chopping

The general conclusions arrived at in this Report, which is designedly wide in its terms, afford sufficient proof of the need for representation to be made to the proper quarters—Board of Education, Home Office, and Local Government Board—in favour of steps being taken to provide for adequate reports upon all educational work and training either to central or local authorities.

APPENDIX.

British Association for the Advancement of Science

SPECIAL SCHOOLS COMMITTEE.

Chairman Mr W D EGGAR
Secretary Mrs W N. SHAW.

Professor R A GREGORY, Mr J L HOLLAND, Dr C W KIMMINS, and Mr J G LEGGE

DEAR SIR,—The British Association has appointed a Committee to collect and tabulate statistics of the curricula of charitable schools not included in official educational lists

It will greatly assist in this work if you will be good enough to fill up the accompanying paper and post it to the Secretary of the Committee, Mrs W N Shaw, 10 Moreton Gardens, London, S W, before February 10, 1912

Will you at the same time state if it will be agreeable to you for some Member of the Committee to visit your school?—Yours faithfully,

S. J D SHAW,
Secretary to the Committee

British Association for the Advancement of Science.

MEMORANDUM INDICATING THE INFORMATION DESIRED.

Is a Prospectus and Report of the School published? If so, will you kindly forward a copy?

In any case will you favour us with answers to the following questions?

1. Name and address of school.	
2 Is the school under private management or under a Board of Governors?	
3. What fees, if any, are paid for the children?	
4. What number of children—(a) girls, (b) boys—are there in the school?	

5 What are the professional qualifications of the resident officers and teaching staff?	
6 If there are visiting teachers, what are their professional qualifications?	
7 Is the school examined or inspected from the outside? If so, by whom are the examiners or inspectors appointed, and for what examining or inspecting authority do they act?	
8 Please send a copy of the curriculum and the time-table	
9 What number of class rooms are there?	
10 What special provision, if any, is made for the teaching of science?	
11 How are the children occupied out of school hours?	
12 What occupations are taken up by the majority of children on leaving?	

Will you add any further information that you think would be useful or interesting to the Committee?

Mental and Physical Factors involved in Education.—Report of the Committee, consisting of Professor J. J. FINDLAY (*Chairman*), Professor J. A. GREEN (*Secretary*), Professor J. ADAMS, Dr. G. A. AUDEN, Sir EDWARD BRABROOK, Dr. W. BROWN, Professor E. P. CULVERWELL, Mr. G. F. DANIELL, Miss B. FOXLEY, Professor R. A. GREGORY, Dr. C. W. KIMMINS, Professor MCDOUGALL, Drs. C. S. MYERS, T. P. NUNN, W. H. R. RIVERS, *and* F. C. SHRUBSALL, Professor H. BOMPAS SMITH, Professor C. SPEARMAN, Mr. A. E. TWENTYMAN, *and* Dr. F. WARNER, *appointed to inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.*

THE Committee have been concerned with two problems during the year: (1) the completion of their work of last year on the present methods of examining children who were alleged by teachers to be mentally deficient, and (2) the consideration of the psychological factors involved in learning to read and write.

In regard to (1), four members of the Committee drew up a report which has received the approval of the Committee and is submitted herewith.

In regard to (2) the Committee thought the most useful work could be accomplished by inviting certain persons to draw up statements of actually ascertained fact They divided the subject into three heads·—

(*a*) The psychology of the reading process in the case of those actually able to read

(*b*) The psychology of the process of learning to read.

(*c*) The psychology of the writing process

On the nomination of Dr C S Myers, Mr. Frank Smith undertook the first, on the nomination of Professor Spearman, Mr B Dumville did the second, and Dr W Brown undertook the third. The three reports are given below The Committee have also arranged for papers bearing on the theoretical and practical aspects of these problems to be read at the meeting

The Committee desire to express their gratitude to those who have so kindly helped them in their work They desire to be reappointed

Suggestions for the Examination of Mentally Defective Children

Report of the Sub-Committee, consisting of Drs G A Auden, C S Myers, F C Shrubsall, *and* Professor C Spearman (*Convener*)

In attempting to draw up suggestions for the examination of defective children it is necessary to bear in mind that this examination has several more or less distinct purposes In the first place, we require to ascertain whether the child, in his present state, is likely to profit by the instruction given in the normal school No one should be able to answer this question so authoritatively as the teacher who has been trying to impart this instruction to the child Even the necessary checks on the teacher's verdict, to secure uniformity of standard in different schools, to protect children against personal bias, &c , would seem wholly a pedagogical concern, although under existing circumstances these duties devolve very largely upon the school medical officer But it is insufficient to prove that the child is unfit for normal instruction, we have further to determine whether his state admits of any remedy Often it is more or less due to imperfect nutrition, adenoids, abnormalities of the ductless glands, nervous diseases, and so on, which may admit of considerable betterment Here we have an excellent reason why the final verdict on the child in these cases, at least, should rest with the school medical officer

The above, however, does not exhaust the purposes of the examination Intellectual, emotional, or volitional disturbances may arise from very obscure causes, and be almost solely accessible to investigation from the psychological aspect Such investigation may reveal them to be of so limited a character that useful instruction becomes perfectly feasible, if somewhat modified to suit the child's special requirements. It is therefore desirable to submit at any rate some of the defective children to a more exhaustive examination than would come within the ordinary pedagogical or medical scope

In these circumstances it is natural to turn for help to psychology And here we find, among other things, that a large number of ' tests '

have been developed for the purpose in question, and that a vast mass of data has been collected in various countries On the whole, although many amendments in detail have been suggested, competent judges seem unanimous in reporting the tests to be of great value A comprehensive summary of them will be found in Whipple's 'Manual of Mental and Physical Tests,' and they have been referred to in Appendix III to the last report of this Committee

At present the most systematic series of tests appears to be that of Binet, whose latest developments are given in the 'Bulletin de la société libre pour l'étude de l'enfant,' April 1911 Among the most striking instances of their application is that of Goddard [1] But the tests appear to be still far from finality, and it would be unwise to use them without regard to the fact that many investigators are gradually evolving the general principles which should govern their usage

The first of these principles concerns the *reliability* of the tests It has been shown that, in order to obtain consistent results, a test must be of a certain thoroughness, the minimum time required varying largely according to the particular test This aspect has been greatly neglected in the past, and some of the tests now currently recommended appear to be so unreliable as to be of little real use Research is beginning to determine the reliability of different tests, so that much more information on the subject will soon be available

Another principle generally admitted by competent investigators is the absolute need of *diversity* The person who is not versed in psychological method is inclined to pronounce a confident opinion about a child on the strength of one single manifestation—as he believes—of conspicuous intelligence Experiment has shown, on the contrary, that the performances of any person, normal or abnormal, are very unequal, unquestionably defective children have proved themselves occasionally capable of performances astonishing even to those in regular charge of them These two principles of *reliability* and *diversity* are in direct opposition, for instance, to the formation of a definite verdict as to the child's normality on the sole basis of two or three summary tests (such as asking him 'What is a cat?' or making him count his fingers)

The third principle concerns the *relative value* of the different tests It is generally agreed that this varies greatly in the case of normal persons, some tests giving much better information than others, operations of a 'higher' kind (such as reasoning, &c) incline to give more valuable results than sensory or motor tests But in the case of defective children it has been reported that many of the lower (and particularly the motor) tests give information as good as any others, and are more convenient Here again further investigation is wanted

The next principle refers to the *significance* of the results of the tests Opinions are less unanimous, but at least one point may be regarded as definitely settled It has been found that failure to succeed in any particular performance by no means proved incapacity for all performances of the same general form; for instance, failure

[1] See *Pedagogical Seminary,* June 1911; also the *Training School,* 1910, vol. vi., No. 11.

in any one kind of discrimination does not necessarily involve inferiority in other kinds, and similarly as regards memory, reasoning, &c The popular habit of regarding these different forms of intellectual operation as distinct 'faculties' has no foundation in psychology. In further respects opinions as to the significance of these tests still remain much divided Theories, indeed, have been advanced which may prove of great importance; but it would be premature for the present committee to formulate any view until a more general consensus of opinion has been reached

Lastly, it cannot be too strongly emphasised that the successful use of these tests depends very largely upon the observer's training in psychology, experience of testing, and sympathetic understanding of children

On the whole, then, it would appear that to get all the possible use out of these tests requires an elaborate procedure In the more obvious cases of mental defect the current system of examination scarcely admits of radical change at present. For the more doubtful cases, on the other hand, the existing resources seem entirely insufficient To send a child to a school for defectives has very serious consequences for him and for his parents, and there is a possibility of the matter becoming still more momentous in connection with eugenical measures Nothing can be satisfactory short of a systematic examination at properly equipped central institutions. Such institutions are further and urgently needed for the purpose of research, since one of the main lessons to be drawn from the previous investigations is the desirableness of extending them And as one of the chief difficulties in carrying out such a plan would be to find the necessary scientific experts, it seems eminently desirable to take some steps towards encouraging the study of psychology among medical men Several universities have recently instituted a systematic course of training and an examination qualifying for a diploma in psychological medicine But this training will be of little avail for the present purpose unless its pedagogical, no less than its psychological, aspect be duly regarded.

APPENDIX.

Psychological Factors involved in Learning to Read and Write

(a) The Psychology of the Reading Process. By F Smith, *B A , B Sc*

1 Individuals differ greatly in their speed of reading, and rapid readers, in general, show the better comprehension of what is read Speed of reading is influenced greatly by the general quickness of a person's visual perception, and also by other factors.

2. The eyes move forward, when reading, in a series of quick movements separated by rest periods The movements vary greatly in extent, but occupy a fairly regular time, and do not seem to be under direct voluntary control. The intervening pauses occupy much longer time than the movements, but vary greatly even in the same person

Reading occurs probably only during the pauses. Fast readers achieve regular rhythmical movements of the eyes more easily than slow ones. These movements are assisted by lines of uniform appearance, position, and length.

3. The area covered by a given fixation varies with the nature of the subject-matter—it is large in the case of nouns, adjectives, and verbs, but small with the connective parts of speech. The amount read at each exposure is greater than that which occupies the region of clear perception, but less than that which fills the maximum range of vision.

4 It is not yet clear whether the 'total word form' or certain 'dominating' letters and complexes function first in word-perception. Among recent investigators Wiegand argues that the 'total form' is of less importance than single letters, whereas Beer emphasises the importance of the 'total form' for prose, as distinct from poetry It is possible that the same individual proceeds by different methods, according as his purpose is best served at the time

5. Inner speech is generally characteristic of reading, and is usually a combination of motor and auditory elements Lip-movement is commonly found in children and backward adults, but it is a hindrance, and disappears in proportion as rapidity and understanding are acquired. There are two stages in the function of inner speech: a preliminary word-sound is called up immediately by the visual form, but the full inner utterance is held back until there are enough visual and motor data present to suggest the total meaning of the whole idea.

6 Meaning seems usually to be felt as belonging to the sentences and the large units Words are felt as having a part in the total, but they are only links to a place where a new meaning will emerge The consciousness of meaning belongs to the feelings Sensory imagery occurs usually with the substantives, but the meaning is not in the image: it is in the feeling which attaches to the image and the word together [1]

References

Professor Huey's 'Psychology and Pedagogy of Reading' (Macmillan Company) gives a bibliography which is complete to 1907 More recent publications are —

C. F. Wiegand: 'Untersuchung über die Bedentung der Gestaltqualität fur die Erkennung von wortern'—*Zeits f Psychol*, Bd. 48, 1908

Dodge: 'Eine Experimentelle Studie der visuellen Fixation'—*Zeits f. Psychol*, Bd 52, 1909.

Beer · 'Die Abhängigkeit der Lesezeit von psychol. und sprachlichen Faktoren'—*Zeits f. Psychol*, Bd. 56, 1910

F. C. Dockeray · 'The Span of Vision in Reading, and the Legibility of Letters'—*J. of Ed. Psychol*, i., 1910.

A Prandtl · *Zeits f. Psychol*, Bd. 60, 1911.

(*b*) *The Mental Processes involved in Learning to Read.*
By B. Dumville, *M.A.*

In reading, both *perception* (visual in normal cases) and *apperception* play a part. If the former alone took place, there would be little

[1] Various members of the Committee object to this view of the nature of meaning.

more than a feeling of familiarity which would disappear with the word. But with apperception the recognition involves more than the results of complication [2]: it includes the play of *associated* elements on the visual impression

The associated elements in question are the *sound* [3] and *meaning* Complete reading involves both sound and meaning being aroused But the latter is the more essential For the object of reading is the gathering of the meaning represented by the printed words Still, in all normal cases the sound is also a factor Some,[4] indeed, consider it essential in such cases It is certain that with normal children the sound forms the link between printed word on the one hand and meaning on the other And all methods of teaching to read concern themselves with it 'Reading is thus doubly an apperceptive process' [5]

Now, provided that the child is not required to attack pieces which are beyond his vocabulary, we may assume that both sound and meaning are already well established and firmly associated before he comes to the task of learning to read This latter, then, involves in its essence the development of the visual percepts of the words and, concurrently, the association of these with the sound-meaning complexes already in existence

This process can go on in several ways The visual percept of each word may be developed and facilitated without any conscious attempt to analyse the printed form into parts [6] And the concurrent process of

[2] In Stout's sense

[3] The word *sound* must here be understood to include 'the reinstatement of the spoken word, partly by means of auditory-motor images, partly by means of actual movements of articulation' (Sully, 'Teacher's Handbook of Psychology,' new edition, pp 194-5)

[4] *E g*, Storring (*vide* Meumann, *Vorlesungen*, ii, pp 273 4) But according to the school of Charcot, visuals may gather the meaning without the intervention of the sound 'For reading in the case of such individuals the path from the centre of sight to the centre of meaning will be required, there exists thus in this case a direct connection between the centre of sight and the centre of meaning' (Meumann, *op cit*, p 279) Quantz has shown experimentally that 'Lip-movement is a serious hindrance to speed of reading, and consequently to intelligence of reading The disadvantage extends also to reading aloud' ('Problems in the Psychology of Reading,' *The Psychological Review—Monograph Supplements*, vol 2, 1897-99, p 50) W B Secor, after experimenting, concludes 'Both articulation and audition are to be regarded as aids in reading rather than absolutely necessary elements' And further · 'It is possible to read without articulation and audition' ('Visual Reading,' *American Journal of Psychology*, January 1900, p 236)

[5] Sully, *ibid.*

[6] 'In the recognition of words the greatest parts are played by the initial and final letters (Zeitler and Huey), especially the capital letters Next come the letters extending above the line, then those extending below, the least important parts being played by those within the line Further, the upper part of words is more important than the lower part, and the left half of words is more important than the right' (Meumann, *op cit*, pp. 246-7) The general appearance of a word, due to the presence, or absence, or different arrangement of the various kinds of 'determining letters' above mentioned is called by many German writers its *Gesamtform* This is without doubt the most important means of recognition for *adults* And it is probable that the same is true for those children who begin the task of learning to read in the way described above

association may concern itself principally with either term of the association already existing in the child's mind—with *sound* or with *meaning*.

It is rare to find the meaning emphasised above the sound. Yet something of this kind occurs in the early stages of the method advocated by Herr Taubstummenlehrer Malisch of Ratibor, and described by Meumann[7] 'Thus, an egg, a jug, a hat, a fish, &c, are drawn, naturally in very schematic form Then in the picture—*e g*, in the oval of the egg—the word *egg* is written. The child seizes this inscription as a sign '[8] Further, as Meumann himself points out, the thing itself can be placed by the side of its sign Some teachers, for instance, have been known to label all the things in the schoolroom with their names Usually, however, the sound of each word is emphasised at the same time This greatly assists the process of seizing the purport of the sign For the sound is already understood and used as a sign for the thing But there have been instances in which the sound could not be clearly perceived in any way, and in which, consequently, all the emphasis had to be placed on the thing or meaning This was the case with the Wild Boy of Aveyron This boy was unable to speak, and his hearing—at least for the sounds of speech—was of little, if any use Yet M Itard succeeded in teaching him some common words and their meanings by the aid of sight alone[9]

Usually, however, as already stated, the sound of the word receives a large share of attention And this is only natural For the sound constitutes, as it were, a handle to the meaning, the latter being definitely grasped by means of it

When the child perceives and apperceives the printed word in this way, he is said to learn by the *Look-and-Say Method.*

But the development of visual percepts of words and the association of these with the sound-meaning complexes proceed on a very different plan when the *Phonic Method* is adopted In this method, no attempt is made during the early stages to facilitate the perception of words by attention to them *as wholes* Nor is any use made of the sound-meaning complexes which already exist Instead of this, attention is directed to the perception of *letters* on the one hand and of the *elementary sounds* corresponding to them on the other, and between each pair (letter and sound) an association is made The letters are now presented in combination—as syllables or words The corresponding sounds are aroused and combined to form the spoken forms of those syllables or words[10] When once all the letters have been dealt

[7] *Op cit*, pp 229-31 It is obvious that with deaf-mutes much more attention must be given to the meaning than is necessary in normal cases Yet even here the 'sound' can be attended to in the sense that the movements of articulation can be observed and to some extent imitated And astonishing results have been obtained in this field

[8] Meumann, *op cit*, p 230

[9] 'Rapports et Mémoires sur le Sauvage de l'Aveyron,' Paris, Alcan, 1894, p 76. An English translation was published as far back as 1802, but seems now hard to obtain A copy exists in the British Museum

[10] Somewhat serious difficulties arise in connection with this analysis and synthesis 'A "word" as read is both a visual and an auditory-motor complex, and it does not follow that both these complexes admit of being split up into the same components. Thus, while letters are evidently the constituent units of

with, and when some practice in combination has been done, it is possible, in so far as the language is strictly phonetic in spelling, for the child to attack any word with a fair measure of success: he may be able to produce the spoken form unaided, even if he has never seen the printed form before

But such 'barking at print' is not *reading* This, as we have seen, involves gathering the *meaning*. And in so far as the child's attention is absorbed with the process of deciphering the words, no true reading can occur But after each act of deciphering the resulting sound-combination strikes the child as familiar. It is a word with which he has already a meaning associated And as less and less attention is required for the process of deciphering, more and more can be given to the meanings aroused Thus true reading begins

But such reading as this would be extremely halting and laborious By whatever method a child is taught, he comes ultimately to read in much shorter time than any which would allow of deciphering Practically all the experiments which have been made with the object of investigating the processes which take place in reading, in the case of those who have already acquired the art, confirm the view that reading is by word-wholes—sometimes, indeed, by sentence-wholes Thus Javal, Huey, and Dearborn have shown that the eye only makes two or three pauses, each of a small fraction of a second (usually $\frac{1}{5}$, though varying much) in each line, the swift movements between these pauses being too rapid to enable any distinct perception to occur. By tachistoscopic experiments, Cattell showed that 'the shortest exposure which would permit the recognition of single small letters and capitals sufficed also for the recognition of short words, and that long words needed but one-thousandth of a second more'[11] Additional experiments by Zeitler, Erdmann and Dodge, Goldscheider and Muller, Messmer, and others confirm these results Huey further found that four readers, whom he tested, proceeding as fast as possible, read

50 letters	in an average of		15 7	seconds
50 four-letter words	,,	,,	17 3	,,
50 eight-letter words	,,	,,	19 6	,,

In all these results there is hardly a word to suggest that we read by the aid of phonic principles. The only inharmonious note is that of Goldscheider and Muller, who think that the 'determining letters'[12] may suggest the word by reason of their sounds being aroused. But 'further investigation has not justified Goldscheider and Muller's conclusion. . . . The word-sound seems usually to be suggested as a whole.'[13]

words *as seen*, they are far from being the constituent units of words heard and spoken, the wholes in the latter case being clearly other than a mere aggregation of the letter sounds, even when the proper phonetic value is given to these' (Sully, *op cit*, p 196) Meumann, who recommends the Phonic Method, is nevertheless fully alive to these difficulties, and criticises severely the attempts of Olivier (Lautiermethode) and Spieser (begriffliche Methode) to overcome them (*op cit*, p 219). It may be said, however, that these difficulties are not perhaps so real as they are made to appear, especially in the case of a language which is consistently phonetic in its spelling.

[11] Huey, 'The Psychology and Pedagogy of Reading,' p. 73.

[12] See footnote on p. 332

[13] Huey, *op cit*, p. 146

Now these results apply to *all* practised readers, to those taught by the Phonic Method as well as those brought up on Look-and Say. In Germany, indeed, the Phonic Method is almost universal How, then, does the child taught by the Phonic Method arrive at this instant recognition of words as wholes?

Meumann asserts that 'the development of the reading (and writing) processes is governed by the law of the fusion of isolated acts into compounded acts through practice '[14] 'For,' he tells us, 'the procedure in reading is the same as in all willed performances· all the external performances and movements become gradually automatic through the natural process of their continued repetition and practice.'[15] But he gives us no indication as to which are 'the *external* performances' and which remain as the chief instigators of the whole procedure That this latter position is occupied by a few 'determining letters' *suggesting their sounds* has already been dismissed

Meumann does, however, make some further attempt to explain what takes place He likens the acquirement of reading to that of piano-playing from notes [16] But throughout all this analogy, Professor Meumann has failed to note a most important difference The child at the beginning of the process of learning to read *can already talk.* To make the learning of piano-playing correspond to the learning of reading, we should have to suppose a child *who could already play on the piano* before beginning to learn from notes; and not merely a few easy pieces, but *practically all the pieces he is afterward to play from notes* In such a case it would not be necessary for the child to render a number of 'external performances' automatic by laborious repetition *They are already automatic!* It would only be necessary for the child to perceive the notes with sufficient clearness to produce *what he can already do* In short, the child who comes to the learning of reading can already use and understand words He has only to connect these ready-made activities with the sight of the printed matter

What really happens in the case of the 'Phonic' child is that, as he masters the difficulties of deciphering, he has more attention freed for the printed word as a whole and for the corresponding sound-whole These are respectively at the beginning and end of the struggle with each word And as that struggle absorbs him less, his attention can pass more freely between the extreme terms He thus forms the essential association—that, namely, between printed whole and sound-whole In other words, he gradually succeeds, in spite of (or, if preferred, alongside of) his phonic training, *in reading by Look-and-Say*

His phonic training does, indeed, confer upon him the advantage that when his rapid reading is arrested by a difficult word he can resort to the process of deciphering Thus he has a greater mastery over his words than a child who could *only* attack them by Look-and-Say [17]

But it is found that the Look-and-Say method, whenever it is employed with intelligent children, and always when it is used by intelligent teachers with normal children, involves a more or less subconscious process of analysis and synthesis which secures the same

[14] *Op cit*, p 260 [15] *Op cit.*, p 258 [16] *Op cit*, pp 259 60
[17] *Vide Judd,* 'Genetic Psychology for Teachers,' p 254

advantage. Thus, Mr. E. J. Gill, of the University of Sheffield, has examined the children of three schools adopting different methods of reading—Phonic methods in two cases and a variety of the Look-and-Say, known as the 'Sentence' method, in the other one. He examined the children in both reading and spelling. But his results in spelling are of most interest in the present connection. They warrant the conclusion that 'the sentence method of teaching reading produces, in a much shorter time, a spelling efficiency at least equal to that produced by synthetic methods; in equal times a greater efficiency'.[18] Still more striking is the fact that at the school 'where letter-sounds are not the basis of the early reading lessons, we have the highest percentage of words spelt on phonic analogies. The children have arrived at the phonic analysis of words almost unaided, and seem to rely upon it more than children of the same standing in other schools where synthetic methods of teaching are the rule. A better illustration of the innate analytic disposition of the human mind could hardly be advanced.'[19]

We see, then, that, taking the word *reading* in its strict sense—the fairly rapid apperception of words as indicating sound-meaning complexes—there is only *one* method, viz., Look-and-Say. But since this process is often in danger of breaking down before difficult words, especially in the early stages, the process of deciphering which has been described as the Phonic Method is a valuable support. When the early stages are occupied entirely by the process of deciphering by means of letter-sounds, the teacher is *said* to adopt the Phonic Method, and the fact that the Look-and-Say Method supervenes is ignored. When real reading (*i.e.*, Look-and-Say) is attempted from the commencement and the process of deciphering is arrived at more or less subconsciously on account of the gradual understanding of the powers of the letters which develops, the whole method is usually called Look-and-Say. It is obvious, however, that neither system confines itself to what is indicated by its name.

Still more misleading are the terms *analytic* and *synthetic*, which are often applied to the Look-and-Say and Phonic methods respectively. *Both* terms should be applied to the Phonic Method. For synthesis cannot occur until analysis has produced the elements which are to be combined. And the Look-and-Say Method *in its essence* is neither analytic nor synthetic, in the sense here indicated by those words. It has sometimes been called the Chinese Method, the reason being that, as in the case of the Chinese language, the child learns to recognise each word *as a whole.*

All writers admit that Look-and-Say is the chief goal for the beginner. All also admit that some analysis and synthesis must take place in order to render possible the process of deciphering in the case of difficult or new words. Dispute arises as to whether this analysis and synthesis should take place at the very beginning as a special and definite exercise or whether Look-and-Say should take precedence throughout, analysis and synthesis developing incidentally. The two

[18] Article on 'The Teaching of Spelling' in *Journal of Experimental Pedagogy*, June 5, 1912, p. 315.
[19] *Op. cit.*, p. 313.

most prominent writers in this field—Meumann and Huey—have come to diametrically opposite conclusions Meumann decides for Phonic methods in the early stages, Huey for Look-and-Say. It should be noted, however, that the former is dealing with a language which is very largely phonetic in its spelling, the latter with one which is very irregular—more irregular than most people suppose There are not wanting strong advocates of the early use of the Look-and-Say Method, even in Germany And if its superiority could be demonstrated for such phonetically spelt languages, it would *a fortiori* be assured for our own tongue.

(c) *The Psychology of Writing* By WILLIAM BROWN, *M A , D Sc*

A complete psychological study of the processes involved in writing would include many preliminary investigations into the acquirement of skill in motor activities generally, the conditions of voluntary control of such activities, and the nature of their dependence upon the neuro-muscular system of the individual at different ages Much work of this general nature has been carried out during the last few years, especially in America and Germany, and precise and valuable results have been obtained Less has been done in connection with the actual problem of writing, although sufficient to demonstrate the great value of psychological research on subjects of this nature Among many excellent investigations those of Professor Meumann are perhaps the most important Meumann considers that the variations of form, pressure, and time-relations observable in the writing of adults, and even in that of children, originate not so much in the hand as in the brain ' Hand-writing is essentially brain-writing ' Indeed, Preyer had previously observed that if one moves the pen with the mouth or the foot the same characteristics occur It is the nature of the innervations coming from the cerebral cortex, the form and extent in which they are synthesised, that is the main determinant of the character of the handwriting Meumann has investigated variations of pressure in handwriting by getting the subject to write on a strip of paper stretched over an aluminium plate The aluminum plate is supported on three levers running down below to one point, through which the pressure exercised on the plate is transmitted to a pneumatic capsule From this the pressure is transmitted to a second capsule furnished with a lever which traces a ' pressure-curve ' on a slowly revolving smoked drum The results show that adults fall into two types as regards writing—the masculine and the feminine type The former write with greater pressure and somewhat slower than the latter, the pressure varying in a definite manner, so that there is in each word a point of maximum pressure With some individuals this maximum is at the beginning of the word, with others at the end As the speed of writing increases, the pressure increases. In the feminine type the pressure-curve has several maxima, and increased speed is accompanied by diminished pressure

The pressure-curve for children is quite different from both the above types There is no rhythmic writing-curve Each single letter —with beginners each single stroke—is written with equal pressure.

Again, each stroke is written with approximately equal speed. Thus, 'whilst the adult writes the entire word or at least a large part of it with a single voluntary impulse, the child has to employ as many single voluntary impulses as there are letters or even strokes.' The development of the child's handwriting therefore takes the following course: (1) the writing becomes more rapid; (2) 'the isolated impulses fuse to one complex or aggregated impulse with rhythmical subordination of the single pressures to a chief or main pressure, until the innervations of a word form a single unitary act, in which with one decision the entire word is willed and produced.'

Pathological cases throw some light upon the nature of the writing-function. Sommer had a patient who was unable to write certain letters of the alphabet from dictation, yet quite able to write entire words containing these very letters. (Compare the analogous case of reading without spelling, which tachistoscopic experiments show to characterise the reading of adults.)

Analytic v. synthetic method in teaching writing. As with reading, the synthetic method is the more valuable, though it should be supplemented by an exact knowledge of the phonetic analysis of speech. As inner speech invariably precedes writing, there should be, as Meumann says, 'the closest possible connection between reading- and writing-instruction.'

Correlation of writing with intelligence is small, and probably skew. This and other matters will be more fully explained at the meeting.

The Overlapping between Secondary Education and that of Universities and other places of Higher Education.—Final Report of the Committee, consisting of Sir H. A. MIERS *(Chairman)*, Professor R. A. GREGORY *(Secretary)*, Mr. D. BERRIDGE, Mr. C. H. BOTHAMLEY, Miss L. J. CLARKE, Miss A. J. COOPER, Miss B. FOXLEY, Principal E. H. GRIFFITHS, *and* Professor A. SMITHELLS, *appointed to inquire into and report thereupon.*

SCHOOL CANDIDATES IN EXAMINATIONS ABOVE UNIVERSITY ENTRANCE STANDARD.

THE examinations which seem to be most important from the point of view of overlapping of secondary and university education are:—

1. The Intermediate and the Final examinations for the degrees of B.A. and B.Sc. of London University.

2. The Higher Local examinations of the Universities of Oxford and Cambridge.

The subjoined statistics referring to these examinations are of interest. The numbers have been determined from the published class lists in the case of Cambridge, but those relating to the universities of Oxford and London were supplied officially.

University of London

Exams	Total No of Candidates during Academic year 1909	No of Candidates giving a School as place of preparation
B A		
(1) Intermediate	868	216
(2) Final	345	7
B Sc.		
(1) Intermediate	807	257
(2) Final	408	8
	University of Oxford—1910.	
Higher Local	328	212
	University of Cambridge—1910.	
Higher Local	1,120	509

The general result is, therefore, that about twenty-eight per cent. of the London Intermediate candidates are prepared at school, about fifty per cent of the Cambridge Higher Local candidates, and about sixty-six per cent of those taking the Oxford Higher Local examinations

SECONDARY SCHOOLS RECOGNISED BY THE BOARD OF EDUCATION.

The inquiry concerning schools of this group was conducted by means of a printed form of questions, between 600 and 700 copies of which were issued to the chief education officers of administrative counties and county boroughs, by whom they were distributed to the schools within their respective areas The Committee is greatly indebted to these officers for the interest they showed in the inquiry and the trouble they took to get the desired information Without their help it would have been practically impossible to make anything but an imperfect survey, whereas complete returns were received from several administrative areas, and in some cases the education officer furnished useful information derived from his official experience Thanks are also due to the head-teachers who took trouble in filling up the forms, in many cases they also added further particulars or gave valuable opinions

Altogether 292 forms were received, and they came from 177 boys' schools in administrative counties, 29 boys' schools in county boroughs, 67 girls' schools in administrative counties, and 19 girls' schools in county boroughs

It is difficult to frame a definition of overlapping which would be generally applicable, but *for the purpose of this inquiry* the passing of a university matriculation examination, or its equivalent, was adopted as the boundary line Head-teachers were asked (1) whether in their opinion there is overlapping between the work done in secondary schools and that done in universities or other places of higher education; (2) how many pupils in the particular school had during the last three years passed a matriculation examination and read for a further university examination whilst still at school, or, without taking a definite course, had remained at school for a substantial period after passing the said examination Information was asked for in respect of ordinary pupils, and also in respect of Board of Education bursars and pupil-teachers, whose presence has introduced a new feature into

secondary schools during the last few years. Bursars and pupil-teachers are over the age of sixteen at the time of their recognition as such, and it is not improbable that overlapping occurs more frequently with them than with ordinary pupils. The head-teachers were also asked whether they had any changes to suggest in (1) university regulations concerning the Matriculation Examination and the Intermediate or other examinations; (2) the Board of Education's regulations concerning bursars and pupil-teachers, or (3) the curriculum and organisation of secondary schools.

Boys' Schools in County Boroughs

The schools in county boroughs are in such close proximity to a university, university college, or large technical institute that they are subject to influences which do not operate at all, or operate to a much smaller extent, on the majority of schools in administrative counties, and it seems advisable to keep the two groups distinct

In the newer secondary schools, supported largely or wholly by municipal authorities, there is stated to be no overlapping with the work of higher institutions The maximum leaving age of these schools is seventeen or eighteen, but a large proportion of the pupils do not stay up to seventeen, and the Matriculation Examination is regarded as the school-leaving examination

The head-masters of the long-established (and usually endowed) schools with a leaving age of eighteen or nineteen under their governing scheme state that if a Matriculation Examination is taken as the boundary line, and the examination can be passed by a clever boy at the age of sixteen, or even earlier, overlapping does and must occur in the case of boys who remain for a full school course, i e , up to the maximum age allowed. Some boys stay on for further education, but without any intention of proceeding to a university, and if they are not to waste time they must do work above matriculation standard, others stay in order to compete for university scholarships, and under existing regulations and with the somewhat high limits of age allowed, the standard of these competitions is much higher than that of matriculation, and in some instances is not far removed from the standard of a pass degree, others read for the Intermediate Examinations of the university to which they intend to go, and if the regulations permit, pass the examination before leaving school, but if not, they lighten their university work and materially increase their chance of taking an honours degree The head-masters of these schools, as a whole, regard this kind of overlapping not only as unavoidable, but as having distinct advantages. There is practical unanimity of opinion that the age at which clever boys can pass the existing Matriculation Examinations is considerably below that at which they can with advantage enter a university, with its greater freedom from restraint Generally, opinion seems to be in favour of eighteen as the minimum age for entrance at a university, but there is no marked evidence of any general desire to raise the minimum age for matriculation above sixteen, though some suggest raising it to seventeen.

Many head-masters of schools of this type regard the Intermediate

syllabuses and examinations of London and the newer universities as being essentially school courses and examinations for first-grade schools with a high leaving age Some consider that boys who pass the Intermediate Examination at school should be allowed to take their degree after two years' residence at the university, and point out the relief this would give to parents of limited means; others, including the head-masters of two large well-known schools in two of the largest county boroughs, consider that no examination passed at school should reduce the university course below three years, though some of these would allow the degree examination, but not the degree, to be taken at the end of two years; others are of opinion that all boys who have passed the Intermediate Examination whilst at school should be required to read for an honours degree at the university

The head-master of a large school in the North writes 'So far as my experience goes, the overlapping produces no unsatisfactory result The pupils who pass on to the universities express satisfaction that their school studies have been carried on beyond the matriculation standard Such pupils are impressed by the rapidity and condensation in the treatment of subjects by the university professors Further, the points of view of university and school are sometimes necessarily and beneficially different'

Several head-masters complain that some of the newer universities do work below matriculation standard, and there is practical unanimity of opinion that no boys ought to be allowed, as they often are, to take up residence at a university, whether old or new, until they have actually passed the examination required for matriculation Others state that the work of a good upper sixth form is little, if at all, below the standard at present required for a pass degree

Boys' Schools in Administrative Counties

The head-masters of many schools in small towns and in the country state that their work does not overlap at all with that of higher institutions Although under their schemes they may keep pupils until seventeen or eighteen, few reach matriculation standard, and very few go beyond it Most of the pupils leave before they reach the age of sixteen

Some of these schools, however, send a small proportion of pupils to the universities or larger technical institutions, and many of these pupils, after passing a Matriculation Examination, will continue at school in order to compete for a University Scholarship, and sometimes, but rarely, a boy will pass the Intermediate Examination while still at school In these cases the overlapping is of course of the same nature as in the large towns, and the opinions of the head-masters are practically identical with those already quoted There is no desire that the minimum age for passing the Matriculation Examination should be raised.

Girls' Schools in County Boroughs

In the larger secondary schools in the large towns a fair number of girls remain after passing a Matriculation Examination, but by no means all of them intend to proceed to a university. Those who do

intend to go work for the Intermediate Examination or follow a corresponding course. There is general agreement that a girl ought not to go to a university before the age of eighteen, and also that it is a great advantage for a girl, from the point of view of health and the avoidance of overstrain, to have done part of the work for her degree course while still at school, even though the work may be done in a somewhat different manner and from a different point of view. 'The students all state that though the work has already been taken here (a large northern school), it was taken in such a different way and with so much more detail that no disadvantage has been felt '

One or two girls' schools which work in close association with newer universities make it a definite aim that a girl going to the university shall have at least one year's further work at school between the passing of the Matriculation Examination and going into residence

The overlapping in the case of girls' schools is of the same nature as that in boys' schools, and, on the whole, would seem to be more frequent Head-mistresses are, however, even more emphatic than head-masters as to the advantage of the overlapping, and they lay stress on the greater danger of overstrain in the case of girls.

It is noteworthy that many head-mistresses are in favour of raising the minimum age for matriculation by girls to seventeen, and several consider even eighteen too early an age, as a rule, for a girl to enter a university.

Girls' Schools in Administrative Counties.

In the smaller girls' secondary schools those who stay beyond the matriculation stage are as a rule bursars, or pupil teachers, or girls who intend to enter the teaching profession in some way Here, also, we meet with the same general opinions and practice—*i e* , that if a girl intends to enter a day training college attached to a university, with the view of following a degree course, a year's work of preparation at school should follow the passing of the Matriculation Examination.

The additional year does not, however, seem to be regarded as *necessary* for bursars who wish to go to an ordinary training college, although some bursars will pass the necessary qualifying examination some time before the termination of the bursary.

Secondary Schools and Training Colleges.

In several cases it is represented that the work of the ordinary training college for elementary school teachers overlaps the work of the secondary schools. It is stated that pupils who have been for several years at a secondary school and have passed a Matriculation Examination, possibly one or two years before they enter the training college, have practically to mark time during their first year at the college, with the courses as now arranged. It is represented that at present the colleges do not make sufficient allowance for a school education which is considerably in advance of that received by many of the students who enter the colleges The present courses require modification if they are to meet the needs of this class of pupil,

and the modification should take the direction of less academic work and much larger opportunities for practical training in professional work. It may be stated in this connection that a modified course of this kind has been in operation very successfully for three or four years in the women's department of the day training college at Bristol.

Secondary Schools and Technical Institutes.

In a few cases it is stated that the technical institutions do work which ought to be done at secondary schools, but this complaint is not frequent. Technical schools necessarily cater for students who for various reasons may not have been able to have a full secondary school course, but the absence of any general complaint from town secondary schools would seem to indicate that the local education authorities have not been unmindful of the necessity for proper co-ordination of the technical institute with the schools.

General Suggestions received.—Many of our correspondents express very strongly the view that the mere fact that a pupil has passed a Matriculation Examination or has reached a standard of knowledge equivalent to the beginning of university work is not of itself satisfactory evidence that he can take up residence at a university with advantage. They consider that 'overlapping' cannot be defined solely on the basis of mental attainments, whether determined by examination or by the course of work that has been followed. The proper time for a boy to pass from the school to the university is a question of the state of development of his general as well as his intellectual faculties.

While there is no general desire to raise the minimum age for the Matriculation Examination, it is suggested from several quarters that there should be a lower and a higher Matriculation Examination which would also serve the general purpose of Leaving Examinations, the lower examination being suitable for pupils of sixteen to seventeen, of much the same standard as at present, while the higher examination, suitable for pupils of eighteen to nineteen, would be of a higher standard and possibly with fewer subjects, and should be accepted as qualifying a candidate to follow a course for an honours degree without any further Intermediate Examination.

General Conclusions.

The evidence placed before the Committee shows that a certain amount of overlapping does, in fact, exist between the work of secondary schools and that of universities and other places of higher education. Although individual opinions differ, this overlapping is not generally deplored by representatives either of schools or universities. Head-masters, and especially head-mistresses, are of opinion that a pupil may with advantage remain at school for a year or more after passing the present matriculation examination, or reaching an equivalent standard, and this extension of the school course is regarded by them as particularly valuable for students who intend to prepare at the university for an honours degree. Some head-mistresses consider that to go over the

earlier part of the degree work at school, even though by a different method, is a useful safeguard against mental overstrain on the part of girls.

It is unavoidable that a certain amount of common ground should be covered by the teaching in schools on one hand and at universities and university colleges on the other. When a school course is designed to terminate for average boys and girls where university work ordinarily begins, the cleverer boys and girls will certainly get beyond this standard whilst still at school, unless they are to go to the university at an age which is generally recognised as unsuitable, on grounds other than those of mental attainments. In other words, the more advanced pupils at many secondary schools will always be equal to, or in advance of, many undergraduates who are reading for a pass degree at the university.

Again, some school subjects have to be taught at a university to students who have not previously had the opportunity of learning their rudiments, and many of the students to whom this applies enter the university at a comparatively advanced age.

The relation between certain public schools and the older universities is so intimate that arrangements can be made to prevent overlapping. On the other hand, most of the newer universities arrange their courses in 'years' without any special regard to the requirements of individuals, the result being that students who have just reached matriculation standard may have to work with others who are practically ready for the Intermediate Examination. In these circumstances, it is not surprising that complaints are made on one hand that the university course is too rapid, and on the other that it is too elementary. It seems to the Committee not improbable that undesirable overlapping at any university might to a large extent be prevented if more care were exercised to ensure that the classes were suitable to the particular student.

School Curricula.

Although in the public schools, from which a considerable proportion of boys proceed to the universities, there may be no disadvantage in arranging the work in the upper part of the school on lines intentionally preparatory to the university course, and to some extent overlapping it, the case is quite otherwise in the large number of secondary schools, where the proportion of pupils who will go to a university is small. In these schools, which provide for the bulk of the children of the professional and commercial classes, the great majority of the pupils will pass into active life as soon as they leave the school. There has been, and still is, far too great a tendency to allow the curricula of such schools, especially in the upper forms, to be moulded to the requirements of the small proportion of pupils who will go to a university. But if a pupil going into active life direct from school spends the valuable last years of his school course in work designed essentially as an introduction to a further long course of study, there is grave danger that he will enter upon his career with a number of loose ends of incomplete knowledge, but with no power of applying any of them even to the simplest problems which he will constantly meet in his daily occupation. Advanced work of this kind is very unprofitable because it leads to no definite goal.

In secondary schools in general the pupils who proceed to the universities are not the normal product. They should be regarded as the exceptions, for whom something may be added to or adapted in the ordinary school course; the whole curriculum should not be directed to meet their special requirements to the detriment of the great majority of pupils

The normal course of a secondary school should be designed to meet the needs of the average pupil, and in the upper forms to give him the opportunity of leaving school with a real grasp of some departments of knowledge, complete so far as they go, and having a distinct relation to his future life in both its occupations and its leisure

Recommendations

After consideration of the evidence, the Committee is of opinion —

(1) That students should not be prohibited from taking the Matriculation Examination or its equivalent as soon as they are sixteen, but they should not ordinarily be allowed to enter a university for a degree course below the age of seventeen.

(2) Universities should not provide instruction for the purpose of preparing candidates for matriculation.

(3) Students for degree courses should not be admitted to universities or their constituent colleges until after they have passed the Matriculation Examination.

(4) A university examination subsequent to matriculation should not be allowed to become a school examination

(5) There should be two school-leaving examinations conducted conjointly by the universities or by a representative examining board —

(*a*) Suitable for pupils of about sixteen years of age

(*b*) Suitable for pupils between eighteen and nineteen years of age

The earlier examination (*a*), representing a good general education, and of the same standard as the present London Matriculation or similar examinations, should be accepted for matriculation and for admission to professional courses as those examinations are at present.

The later examination (*b*), of the same general standard as the Intermediate B A or B Sc. examination of the University of London, but not necessarily of the same character or substance, should not be designed primarily for those who intend to proceed to a university, and should admit of some degree of specialisation Under certain conditions, it might be accepted by universities as excusing students from any further examination between their entrance into the university and their degree examination. Only those pupils who have passed the more elementary examination (*a*) should be admitted to the higher examination.

Note by Sir Henry A. Miers.

I have acted as Chairman of this Committee, which was suggested by my Presidential Address at Sheffield, and have been glad to assist in collecting the evidence upon which the Report is based; but my position as Principal of the University of London prevents me from identifying myself in any way with the conclusions adopted in it.

(Signed) H. A. Miers.

APPENDIX

Report of the Consultative Committee of the Board of Education on Examinations in Secondary Schools [1]

Since the Report of the Committee was presented last year the subject of Secondary School Examinations has been dealt with exhaustively in a Report of the Consultative Committee of the Board of Education (Cd 6004, price 2s 6d) As the result of an elaborate inquiry into the origin, growth, development, and present position of external examinations in secondary schools in England, the general principles which should underlie any sound system of external examinations are laid down, and suggestions and recommendations are made for putting them into practice. It is unnecessary here to enter into the detail of the organisation proposed to remedy existing defects, but we may say that it involves the establishment of a system of external examinations held under a widely representative Examinations Council with executive powers This Council would institute certificates of three grades, the awards to be based not only on written work, but also on inspection, on consideration of the whole of the work done by the pupils, and on the marks given to that work by the teachers The certificates would be as follows —

(1) A Secondary School Certificate representing a reasonable standard of attainment for a pupil of sixteen years of age, and to be open to candidates who have been in attendance for at least three years, after the age of twelve, in one or more approved secondary schools, and have reached a class in which the average age is sixteen This certificate would represent approximately the same standard as the present Matriculation Examination, and the written work for it would be the first external examination taken normally by a pupil in a secondary school

(2) A Secondary School Testamur for which no external examination of any sort would be required This testamur would be for pupils who leave before they are sixteen years of age, and would be based upon (*a*) success in the usual internal school examinations, (*b*) the school record The standard of the testamur would be that which would be reached about a year earlier than the Secondary School Certificate Examination

(3) A Secondary School Higher Certificate suitable to the attainments of pupils of an average age of eighteen or nineteen years In standard the examination for this certificate would be two years in advance of the Secondary School Certificate Examination, and be open only to candidates who had been in attendance at one or more recognised secondary schools for a period of not less than four years

It is assumed by the Consultative Committee that the majority of pupils who remain at secondary schools till what may roughly be called university age would most probably have passed the Secondary School Certificate Examination and have spent their subsequent years

[1] This Report was published after the foregoing conclusions had been drafted It is significant that two independent inquiries should have led to practically the same recommendations concerning Leaving Examinations

at school in higher or more specialised work. Candidates for the higher examination would, therefore, take fewer subjects than those in the lower.

Upon the specific subject of the relation between the work of secondary schools and that of universities the Consultative Committee makes the following observations:—

'We realise that it is a great convenience that pupils in secondary schools who intend to proceed to a university should take, while at school, an examination which is accepted for matriculation purposes. Further, we are aware that many pupils are able to pass such an examination one, two, or even three years before they leave school, and are fit to take a more advanced examination at the end of their school course. It seems clear that an appropriate examination should be provided for such pupils. They require the stimulus that a good examination gives, and they deserve the credit which attaches to their attainments. Moreover, we see no reason why success in an examination taken at this period of school life should not excuse a candidate from part of the university examinations which he would otherwise have been required to pass. But at the same time we feel that, for various reasons, there are considerable objections to the plan by which pupils in secondary schools take university examinations which form part of a degree course. In the case of Matriculation Examinations we think it is far preferable that pupils who are going to a university should take an equivalent examination which in the main is also suitable for the other pupils in their class. To the school use of subsequent degree examinations the objection is that it leads to confusion between university and school education. We are anxious to encourage as many pupils as possible to obtain a real university education, and we think that one of the main inducements to do so is removed if university degrees, or parts of degrees, can be secured by pupils in secondary schools. Boys and girls who pass an Intermediate Examination at school are sometimes deluded into the idea that they have had a university education, and both they and their parents are apt to think that it is not necessary to go further. We think, therefore, that it is educationally unwise to allow in secondary schools any university examinations which form part of the normal degree course. We do not, of course, wish to keep advanced pupils marking time till they go to the university. Some good examination of an advanced kind should undoubtedly be provided for them, and success in such an examination might well qualify them, when they reach the university, to take up their university studies at a more advanced point, though without shortening the normal period of university life. But the examination should really be a school examination, and should have nothing in its nomenclature to give a false impression of what it really is.'

Report on Diffusion in Solids. By CECIL H DESCH, *D.Sc , Ph D.*

[Ordered by the General Committee to be printed *in extenso*]

THE occurrence or non-occurrence of diffusion in solid substances is of fundamental importance for the theory of solid solutions and isomorphous mixtures In order that any mixture of substances in the solid state may be legitimately regarded as a solid solution it must be shown that diffusion is capable of taking place within it from regions of high to those of low concentration The ambiguity which at present exists in respect to this question is due in part to ambiguity in the definition of the solid state, and in part to differences of opinion as to the facts The popular distinction between fluids and solids is traversed by the more scientific classification into amorphous and crystalline substances It is evident, however, that such substances as the glasses, although connected by all possible gradations with liquids on the one hand, and sharply separated from crystalline substances on the other, yet possess most of the properties commonly associated with solids, whilst the liquid crystals of *p*-azoxy-anisole, for example, although definitely crystalline, cannot be regarded as solid bodies in any sense of the word

The following classification,[1] then, represents the possible states that may be assumed by a substance, although any one substance is not necessarily capable of assuming all of these states :—

ISOTROPIC	ANISOTROPIC
Gaseous.	Crystalline, including liquid crystals and one or more solid crystalline modifications
Liquid.	
Amorphous or glassy.	

Diffusion takes place in liquid crystals in apparently the same manner as in isotropic liquids,[2] and they are therefore omitted from consideration in the present Report On the other hand, both amorphous and crystalline solids are considered. The former class is restricted to the natural and artificial glasses, whilst the jellies, which are undoubtedly of a colloidal character, are treated briefly at the close on account of the importance of certain periodic phenomena observed in them for the general theory of diffusion The materials in which diffusion has been either observed or suspected are treated in the following order Glasses (p 349); metals (p 351); minerals (p 367), salts and organic crystalline substances (p 368), these sections being in some cases sub-divided for greater convenience A short summary of the evidence concludes the Report (p. 371)

[1] Modified from that given by G. Tammann, 'Krystallisieren und Schmelzen (Leipzig, 1903), p. 5.

[2] O. Lehmann, 'Flüssige Krystalle' (Leipzig, 1904), p. 76.

Diffusion in Glasses, and Devitrification.

The production of coloured glass by the application of a layer of strongly coloured glass to a thicker colourless mass involves diffusion, but the temperature employed is so high that the glass is soft, and cannot be regarded as solid The colouring matter does not appreciably diffuse at atmospheric temperatures Thus, a sheet of fourteenth-century ruby glass, 5 mm thick, was found on microscopical examination to be built up of 55 coloured and 88 colourless layers, the boundaries between which were yet distinct, although under a higher magnification zones of intermediate shade, which may have arisen during the process of manufacture, could be detected [3] The observations on diffusion in glass at moderate temperatures are almost entirely limited to experiments depending on electrolysis, which are described in the following section The process of devitrification, however, involves diffusion, although only through comparatively small distances, and the evidence on this point may be briefly reviewed

The formation of crystals in a glassy material (devitrification) is strictly comparable with the process of crystallisation from a liquid, and its course depends on two factors—the number of centres appearing in a given time—and the linear velocity of crystallisation [4] Quantitative measurements have been made in the case of glassy borates,[5] and numerous observations of the devitrification of amorphous organic compounds have been recorded [6] In silicate glasses the crystals formed are usually very minute They may become so numerous, when the glass is maintained for a long time at a suitable temperature, as to result in complete opacity (Réaumur's porcelain) [7] The formation of much larger crystals during the slow cooling of glass has been observed in a few cases Thus, a quantity of 400 tons of glass having escaped from a furnace, the slow cooling of the mass led to the formation of spherulites [8] In this case the glass was an almost pure mixture of silica, lime, and soda, and the crystals were entirely composed of wollastonite. In a similar accident, in which the glass also contained much magnesia, very large spherulites of diopside, up to 4 cm in diameter, were formed, together with wollastonite [9] It is to be noted that the spherulitic mode of crystallisation is most liable to occur when the crystals separate at a temperature below the metastable limit [10]

Similar conditions are observable in blast-furnace slags, which may be of any texture from that of a pure glass to that of a stony, minutely crystalline mass A large number of minerals have been identified in

[3] J Fowler, *Archæologia*, 1880, **46**, 65.

[4] G. Tammann, *Zeitsch. Elektrochem*, 1904, **10**, 532 ; 'Krystallisieren und Schmelzen,' p. 148.

[5] W. Guertler, *Zeitsch. Anorg. Chem*, 1904, **40**, 268.

[6] O. Lehmann, 'Molekularphysik' (Leipzig, 1888), i, 707.

[7] Experiments conducted 1727–29.

[8] F. Fouqué, *Compt rend.*, 1899, **109**, 1.

[9] L. V. Pirsson, *Amer Jour Sci.*, 1910 [iv.], **30**, 97.

[10] J. Chevalier, *Min. Mag.*, 1909, **15**, 224.

such slags,[11] and minute crystallites, which from their form must have segregated from the mass after it became rigid, may often be detected.[12] The early stages of devitrification are easily seen in slags which have been granulated by means of air or water.[13]

Natural glassy rocks offer a still better series of examples. Here, again, all stages of devitrification may be observed, the spherulitic mode of crystallisation being frequent, as in rhyolites. It is sometimes possible to show that the crystallisation must have taken place at a comparatively low temperature. Thus, in the pitchstones of Arran, the phenocrysts are of augite or enstatite, but the minute crystallites which are so characteristic of that rock are of hornblende, a low-temperature mineral.[14] The great viscosity of the mass at the time of formation of the hornblende is shown by the clear areas, free from microliths, surrounding the crystallites. Similar crystallites are found in the lava of Mauna Loa,[15] whilst the extreme slowness of devitrification is shown by their absence from some recent lavas, even with a high percentage of iron, as that of Kilauea. Remelting the dolerite of Rowley Regis also yields a clear glass. That the process of devitrification—that is, of passage into the stable condition—proceeds to completion if given sufficient time is shown by the fact, noticed by Harker, that glassy rocks of Palæozoic age are almost unknown, although many rocks of that period show, by the presence of perlitic and other structures, that they have previously been glassy. The effects of devitrification may be produced artificially by heating pitchstones and other glassy rocks.[16]

The crystallites formed in all the above instances are of different composition from the glassy mass, and their formation therefore involves diffusion. The devitrification of such a substance as silica, however, is merely a process of molecular change, not necessarily accompanied by diffusion. Some geologists have attributed still greater importance to the growth of crystals in a glassy magma at low temperatures, and have explained a number of structures frequently observed in rocks to the growth of previously formed crystals at the expense of a small quantity of glassy ground-mass.[17]

Porcelain is probably partly glassy and partly microcrystalline. The diffusion of solid carbon, either in the amorphous form or as graphite, into porcelain at 1000°-1500° has been recorded on more than one occasion.[18] The mechanism of the process has not been studied, but the presence of the carbon at a considerable depth below the surface has been determined both microscopically and chemically.

[11] See, for instance, W. Mathesius, *Stahl u. Eisen*, 1908, **28**, 1121; M. Theusner, *Metallurgie*, 1908, **5**, 657.

[12] H. Vogelsang, 'Die Krystalliten' (Bonn, 1875).

[13] C. H. Desch, 'The Chemistry and Testing of Cement' (London, 1911), p. 98.

[14] A. Harker, 'The Natural History of Igneous Rocks' (London, 1909), p. 225.

[15] E. S. Dana, *Amer. Jour. Sci.*, 1889 [iii.], **37**, 441.

[16] F. Rutley, *Proc. Roy. Soc.*, **40**, 430.

[17] J. W. Judd, *Quart. Jour. Geol. Soc.*, 1889, **45**, 175.

[18] R. S. Marsden, *Proc. Roy. Soc. Edin.*, 1880, **10**, 712; J. Violle, *Compt. rend.*, 1882, **94**, 28.

The Electrolysis of Glass and Porcelain

Very interesting results have been obtained in the course of studies of the electrolysis of glass The electrical conductivity of heated glass, first observed by H Cavendish,[19] was measured and shown to be electrolytic in character by H Buff,[20] who was followed by many other workers It was even found possible[21] to construct a copper-zinc cell with an intervening plate of glass as the electrolyte, a measurable E M F being obtained at temperatures of from 50° to 120°. If two concentric glass bulbs are used, of which the inner contains a solution of copper sulphate and the outer one of zinc sulphate, with platinum wires as electrodes, a Daniell cell of high resistance is obtained[22] A more detailed study revealed some remarkable facts[23] A stout plate or bulb of soda glass is used as a partition, separating mercury on the one side from sodium amalgam on the other, and a current is passed from the amalgam through the glass to the mercury, a temperature of from 200° to 350° being employed After about thirty hours, an appreciable quantity of sodium is found to have been removed from the amalgam and transferred to the mercury, the glass meanwhile remaining clear When lithium amalgam is substituted for sodium amalgam, the current passes, and sodium appears in the mercury cathode, followed after a time by lithium At the same time an opaque layer of silica appears at the anode surface and gradually spreads through the glass A glass originally containing 2 4 per cent of potassium and 13 4 per cent of sodium was found after an experiment to contain the same proportion of potassium, but only 5·3 per cent of sodium and 4 3 per cent of lithium The transfer of sodium follows Ohm's law

The atomic volume of lithium is less than that of sodium When a metal of larger atomic volume than sodium, such as potassium, is used in the form of an amalgam, it is found to be impossible to cause it to enter the glass Gold and copper enter the glass, but do not penetrate completely, and after a time coloured deposits of these metals appear below the surface In a similar manner silver penetrates into lead glass, producing a characteristic structure which is made visible by the silver stain In all these cases the metal entering the glass has a smaller atomic volume than that which is expelled from it, a fact which led Roberts-Austen to regard the process as one in which the atoms of the metal entering pass along tracks or galleries in the glass left by the atoms of the metal expelled The transfer may undoubtedly be described as due to diffusion Warburg's experiments have been recently repeated with certain additional precautions[24]

Diffusion of Gases through Metals

The permeability of certain heated metals to gases, especially of platinum and iron to hydrogen, was observed by H St Claire Deville

[19] 'Electrical Researches' (London, 1879), p. 181

[20] *Lieb Annalen*, 1854, **90**, 257.

[21] W. Thomson, *Proc. Roy. Soc.*, 1875, **23**, 463.

[22] H. Helmholtz, Faraday Lecture, *Trans Chem Soc*, 1881, **39**, i, 277.

[23] E. Warburg, *Ann. Physik.*, 1884 [iii], **21**, 622, W. C Roberts-Austen, 'Third Report to Alloys Research Com.,' *Proc. Inst. Mech Eng*, 1895, 238.

[24] M. Le Blanc and F. Kerschbaum, *Zeitsch. Physikal. Chem*, 1910, **72**, 468.

and L. Troost,[25] and further studied by Thomas Graham in his celebrated memoir on diffusion.[26] The question has been frequently investigated, the metals most commonly employed being platinum and palladium. The permeability of heated silver to oxygen was also determined by L. Troost.[27] In all cases the rate of diffusion increases rapidly with the temperature. The metal exercises a selective action and behaves as a semi-permeable membrane, palladium and platinum allowing hydrogen to pass, but not most other gases, whilst silver transmits oxygen, but not hydrogen or nitrogen. The diffusion is not proportional to the pressure of the gas, but the figures obtained may be explained on the assumption that the molecules of hydrogen diffusing are dissociated into single atoms, and that the diffusion is proportional to the pressure of the dissociated gas.[28] This view has, however, been disputed,[29] adsorption being invoked to explain the anomalies.

The diffusion of nascent hydrogen through metals has also been studied. Thus, when iron is made the cathode in an electrolytic cell, hydrogen rapidly diffuses through the metal, and pressures of many atmospheres are obtained.[30] Platinum, palladium, and nickel show the same effect in a much smaller degree. The diffusion increases very rapidly with the temperature, the increase being of the order of T^{5}.[31]

There is a close relation between the diffusivity of a gas through a metal and the absorptive power of the metal for that gas. The semi-permeable character is extremely well marked, gases other than hydrogen not diffusing through platinum at a white heat, even in sufficient quantity to be detected by means of the spectroscope.[32] The diffusion of gases through colloidal membranes, such as caoutchouc, is of a simpler character, as is shown by the simple proportionality of the diffusion to the pressure and to the temperature.[33] Its discussion does not fall within the range of this Report.

The Passage of Liquids through Metals.

The only liquid which has been observed to pass through metals without destroying their structure is mercury. It was observed in 1713[34] that a complex mixture, consisting essentially of an amalgam of silver and mercury, was able to pass through a plate of silver without rendering it brittle. At a much later date it was shown[35] that mercury

25 *Compt. rend.*, 1863, **57**, 965; H. St. Claire Deville, *ibid.*, 1864, **59**, 102.

26 *Phil. Trans.*, 1866, **156**, 399.

27 *Compt. rend.*, 1884, **98**, 1427.

28 W. Ramsay, *Phil. Mag.*, 1894 [v.], **38**, 206; A. Winkelmann, *Ann. Physik.*, 1901 [iv.], **6**, 104; O. W. Richardson, J. Nicol, and T. Parnell, *Phil. Mag.*, 1904 [vi.], **8**, 1; O. W. Richardson, *ibid.*, **7**, 266; *Proc. Camb. Phil. Soc.*, 1905, **13**, 27.

29 G. N. St. Schmidt, *Ann. Physik.*, 1904 [iv.], **13**, 747. See reply by A. Winkelmann, *ibid.*, 1905 [iv.], **16**, 773.

30 M. Bellati and S. Lussana, *Atti R. Ist. Ven.*, 1890 [vii.], **1**, 1173; 1891 [vii.], **2**, 987.

31 A. Winkelmann, *Ann. Physik.*, 1905 [iv.], **17**, 590.

32 W. W. Randall, *Amer. Chem. Jour.*, 1897, **19**, 682.

33 See, for instance, Graham, *loc. cit.*, and S. von Wroblewski, *Ann. Physik.*, 1876, **158**, 539.

34 Homberg, *Mém. Acad. Roy. Sci.*, 1713, 306 (not actually published until 1739).

35 J. F. Daniell, *Jour. Roy. Inst.*, 1831 [ii.], **1**, 1.

would also pass through other metals, including lead, tin, zinc, and gold. The experiment was devised[36] of causing mercury to flow from one vessel to another at a lower level, using as a syphon a rod of cast lead, bent so as to form two arms of unequal length. Tin may be used in the same way.[37] Copper and brass were subsequently added to the metals exhibiting this behaviour.[38]

It is unlikely that true diffusion in the solid state plays any important part in the process of penetration of mercury in such cases. Mercury dissolves lead or tin, forming a liquid amalgam at the ordinary temperature, and this amalgam probably makes its way through the intercrystalline spaces. It was observed by Henry that the transfer of mercury takes place much more readily through cast lead than through hammered or rolled metal, the intercrystalline spaces of the latter having been closed by the mechanical treatment. The metal also becomes exceedingly brittle during the process, owing to the loosening of the crystalline texture by the action of the liquid amalgam.

Solid Diffusion in Metals.

It is in metals and metallic alloys that the most complete and satisfactory experiments in solid diffusion have been made. The existence of diffusion in solid metals has been fully established, and although doubts may be raised as to the crystalline character of the material through which diffusion takes place, the range of temperature covered by the experiments is so great that it is difficult to conceive of the persistence of amorphous metal throughout.

Leaving the cementation of iron for separate consideration, the earliest scientific record of the production of an alloy by union in the solid state appears to be the observation of M. Faraday and Stodart[39] that iron and platinum could be alloyed by welding at a temperature below that at which fusion could take place. A solid solution is formed in this case.

Several early metallurgical processes have been quoted by W. C. Roberts-Austen[40] as depending on solid diffusion. One of these is the ancient process of extraction of silver from gold by cementation, described by Pliny and others,[41] in which the alloy is packed in a mixture of salts and heated for a long time at a temperature well below the melting-point. The silver is gradually extracted, leaving a residue of solid gold. Another process is that of 'kernel roasting,' in which cupriferous iron pyrites are slowly roasted in air, the final product being a central 'kernel' of cuprous sulphide, enclosed in a shell of ferric oxide, whilst the silver originally present wanders outwards, and appears in the free state as a lace-like coating on the surface.[42]

[36] J. Henry, *Proc. Amer. Phil. Soc.*, 1841, **4**, 56, 84.
[37] E. N. Horsford, *Amer. Jour. Sci.*, 1852 [ii.], **13**, 305.
[38] J. Nicklès, *Compt. rend.*, 1853, **36**, 154.
[39] *Quart. Jour. Sci.*, 1820, **9**, 319; 'Exp. Researches in Chemistry,' 1859, p. 57.
[40] *Phil. Trans.*, 1896, **187A**, 383.
[41] A full account is given by J. Percy, 'Metallurgy of Silver and Gold' (London, 1880), i., 379.
[42] W. C. Roberts-Austen, *loc. cit.*

In both of these processes, however, gases intervene in the reaction, and a porous mass remains, so that it would be rash to attribute the extraction of the metal to solid diffusion without further evidence.

The diffusion of one metal into another has an important influence on the technical process of electroplating. For instance, it was found[43] that when a thick layer of copper was deposited electrolytically on a sheet of platinum, and the compound sheet was heated to dull redness, the copper oxidised and peeled off, leaving a surface which could be cleaned by nitric acid and then presented the appearance of the original platinum. On again heating to redness, however, a fresh layer of copper oxide was formed, and this process could be repeated more than once. The diffusion of an electrolytically deposited layer may even take place at the ordinary temperature Thus a thin layer of copper or brass deposited on zinc slowly disappears, the zinc resuming its greyish-white appearance, and this occurs even when the outer surface is protected from atmospheric action by a layer of lacquer [44]

A platinum wire coated electrolytically with silver and drawn to a smaller diameter through a draw-plate becomes completely soluble in nitric acid, showing that alloying has taken place [45]

A layer of silver, deposited on copper, may be absorbed in course of time if sufficiently thin. As copper is capable of dissolving about 5 per cent of silver in the solid state, absorption will cease when this concentration has been reached. It has been suggested by W Guertler[46] that the absorption might be hindered by the interposition of a thin layer of electrolytic iron, in which silver is not soluble to a measurable extent On the other hand, the interposition of a layer of gold would facilitate diffusion, as this metal forms solid solutions in all proportions with silver and with copper, and also increases the mutual solubility of those metals Copper will diffuse into iron through an intervening layer of nickel [47]

A few minor instances of diffusion into metals at the ordinary temperature may be noticed. The penetration of sulphur into silver, blackening it to a considerable depth, has been recorded,[48] as well as the gradual diffusion of iron into silver in the course of several years [49]

The earliest systematic investigation of diffusion in the solid state is due to W Spring, whose experiments have suggested those of most subsequent workers in the subject It has been observed by Spring[50] that various powdered solids could be formed into a compact mass by the application of high pressure, and further experiments showed that the compression of mixtures of metals with arsenic[51] or with sulphur[52] brought about the formation of arsenides or sulphides

[43] G. Gore, 'The Art of Electro-Metallurgy' (London, 1877), p. 47.

[44] G. Langbein and W. T. Brannt, 'The Electro-Deposition of Metals' (Philadelphia, 1891), p. 133.

[45] Observation of Rouma, quoted by W. Spring, *Ber.*, 1882, **15**, 595.

[46] 'Metallographie' (Berlin, 1910), i., 183.

[47] W. C. Roberts-Austen, *Jour. Iron and Steel Inst*, 1887, i, 73.

[48] Homberg, *Mém. Acad. Roy. Sci.*, 1713, 306.

[49] J. H. Howell, *Nature*, 1906, **73**, 464.

[50] *Bull. Acad. Roy. Belg.*, 1878 [ii.], **45**, 746.

[51] *Ibid.*, 1883 [iii.], **5**, 229. [52] *Ibid.*, 492.

without rise of temperature. Alloys were also formed by compressing their components [53] Of these, the most interesting case is the formation of brass by compressing a mixture of copper and zinc filings The union is very incomplete, and it is necessary to reduce the conglomerate to filings and to repeat the compression five or six times The same memoir describes the formation of fusible alloys by pressure, but the study of the constitution of these alloys was unknown at the time, and in the light of more recent knowledge it is obvious that the production of a readily fusible mass is no proof of chemical union, as the eutectic is merely a conglomerate It was in fact soon shown [54] that fusible alloys could be produced by merely mixing filings of their component metals The temperature at which such a mixture melts is above the true eutectic temperature by an amount which depends on the coarseness of the powders used [55] Other experiments,[56] in which the formation of fusible alloys by pressure was assumed from the compact appearance and low melting-point of the product, are inconclusive for the same reason

These objections do not apply to the later experiments of Spring, in which true interpenetration was shown to occur.[57] Two cylinders of the same metal, accurately faced and freed from grease, were found to adhere firmly at ordinary temperatures and to become fully united on heating Union occurred with all the metals examined with the exception of antimony, and was usually so intimate that when the two cylinders were subsequently separated by force the fracture passed through the metal on one side or the other of the plane of junction Quite similar results were obtained when the two cylinders were of different metals Thus, when zinc and copper were placed in contact and heated to 400° for six to eight hours, the two cylinders became united by a layer of brass 0·8 mm in thickness, whilst copper and antimony similarly formed a layer of the purple alloy. Vapour undoubtedly played a part in some of the reactions recorded, as it was found that a thin layer of brass was formed at 400° even when the zinc and copper were separated by a distance of 0·8 mm , and cadmium also volatilised to a small extent. The intervention of vapour had been previously suggested in explanation of some of Spring's earlier welding experiments,[58] and similar conclusions have been reached by a study of reactions between solid salts in closed vessels [59]

When mixtures of copper and silver filings are compressed into cylinders by the application of a pressure of 8,000 atmospheres, the pressure being maintained for a month at the ordinary temperature, apparently homogeneous masses are obtained which, however, prove on microscopical examination to consist merely of unaltered filings united by adhesion, no interpenetration having take place.[60] It is

[53] *Ber.*, 1882, **15**, 595.
[54] W. Hallock, *Zeitsch. Physikal. Chem.*, 1888, **2**, 378.
[55] C. Benedicks and R. Arpi, *Metallurgie*, 1907, **4**, 416.
[56] C. Drewitz, *Verh. Ver. Beförd. Gewerbefl.*, 1902, **81**, 325.
[57] *Zeitsch. Physikal. Chem.*, 1894, **15**, 73; *Bull. Acad. Roy. Belg.*, 1894 [iii.], **28**, 23.
[58] W. Hallock, *Amer. Jour. Sci.*, 1889 [iii.], **37**, 402.
[59] E. P. Perman, *Proc. Roy. Soc.*, 1907, **79A**, 310.
[60] G. Spezia, *Atti R. Accad. Sci. Torino*, 1910, **45**, ii., 525.

quite possible that in these experiments traces of grease or of oxide hindered perfect contact, as negative results were equally obtained when all the filings were of copper or of silver respectively, whereas Spring's experiments with carefully polished and cleaned surfaces showed that union was sufficiently intimate to tear the metal when an attempt was made to separate it, showing that molecular interpenetration must have occurred to some extent Spezia supports his views by reference to the native copper of Keweenaw Point, Lake Superior, which frequently contains inclusions of native silver[61] which have not diffused into the surrounding copper in the course of geological ages This author also points out the importance of distinguishing between uniform (hydrostatic) pressure and differential pressure causing flow. The latter may be expected to have the greater influence Many experiments[62] show that great hydrostatic pressure, even when long continued, is without influence on the properties of metals

It was an important contention of Spring that only those reactions were favoured by the application of pressure which proceeded with diminution of volume This principle, so important in relation to systems containing a gaseous phase, has received less consideration in respect to solid systems

The investigation of Roberts-Austen, recorded in the Bakerian lecture for 1896,[63] has become classical, owing to the well-designed character of the experiments and to the accuracy of the quantitative method employed The case selected for special study was that of the diffusion of gold into lead Discs of an alloy of lead with 5 per cent of gold were accurately faced and pressed into contact with cylinders of pure lead The specimens were then kept at constant temperature for several weeks, and the diffusion was measured by cutting the lead cylinder into discs and estimating the proportion of gold in each disc by the usual method of dry assay. The gold alloy being placed at the base of the cylinder, diffusion had to take place upward against gravity. The following results were obtained after heating at 165° for thirty days:—

No of Section from Base	Weight of Section in Grams	Au per cent	Diffusivity
1	0 64	0 039	
2	2 33	0 030	0 005
3	2 02	0 015	

Further experiments at different temperatures gave the following values for the diffusivity (expressed in sq cm per day)[64]:—

100°	0 00002
165°	0 005
200°	0 008
251°	0 030
550° (in liquid lead)	3 19

61 C. T. Jackson, *Amer. Jour. Sci.*, 1845 [I], **49**, 81 ; *Compt. rend* , 1845, **20**, 593.
62 See also O. Faust and G. Tammann, *Zeitsch. Physikal Chem.*, 1910, **75**, 108
63 *Phil. Trans.*, 1896, **187***A*, 383.
64 A. Fick, *Pogg. Ann.*, 1855 [ii.], **94**, 59.

As an illustration of the extent of the diffusion, it may be mentioned that at 251° the gold had risen against gravity to a height of 7 cm. in less than a month Further experiments, continued for four years at 18°, showed that at that temperature the gold had risen 7·5 mm , the quantity diffusing in a thousand years being calculated as being nearly equal to that which would diffuse in molten lead in one day [65]

The conditions of these experiments may be examined a little more fully The equilibrium of alloys of lead and gold has been investigated [66] Gold forms two compounds with lead, Au_2Pb and $AuPb_2$ Only the second of these could play any part in the diffusion, owing to the large excess of lead present There is a eutectic point at 215°, so that in the experiment conducted at 251° the transport may have taken place by means of capillary ascent of the liquid eutectic, but the other experiments recorded are at temperatures well below the eutectic point Another experiment recorded in the Bakerian lecture showed that the rate of diffusion of gold in solid silver at 800° is of the same order as that of gold in lead at 200°. In this case a compound is not formed, and diffusion can only take place by the formation of a solid solution

Further experiments on the same lines as those of Spring have been carried out by G Masing,[67] who prepared conglomerates of various pairs of metals by compressing mixtures of the filings in a steel cylinder under 1,000 to 5,000 atmospheres The extent to which union had taken place after heating to different temperatures and for different times was estimated by taking heating curves and comparing them with the curves obtained under similar conditions from alloys prepared by fusion In certain cases the results were confirmed by microscopical examination and by determinations of the electrical conductivity The results show that pressure alone is without influence on diffusion or combination, and serves merely to bring the fragments of the two metals into intimate contact. Intimate mixtures of very finely ground zinc and cadmium, or copper and silver, melt at the eutectic point of the corresponding series, but the mass is at once distinguishable under the microscope from one obtained by fusion, by the absence of the eutectic structure Only traces of a compound are formed when the two metals combine without an appreciable formation of solid solutions, as in the pairs Mg-Pb, Mg-Sn, Mg-Zn, and Mg-Sb (These mixtures were not examined microscopically) Diffusion is perceptible in the case of cadmium and magnesium, which form a continuous series of solid solutions containing a compound MgCd, and of aluminium and magnesium, in which series the compound Al_3Mg_4 forms solid solutions with an excess of aluminium

The alloys most fully studied by Masing were those of bismuth and thallium Heating the mixture of filings, previously rendered compact by pressure, to 120° for 5½ hours brings about the formation of a coloured layer surrounding the particles of thallium This layer con-

[65] *Proc Roy Soc.*, 1900, **67**, 101.

[66] R Vogel, *Zeitsch Anorg. Chem.*, 1905, **45**, 11

[67] *Zeitsch. Anorg. Chem.*, 1909, **62**, 265, see also G. Tammann, *Zeitsch Elektrochem.*, 1909, **15**, 447.

sists of a saturated solid solution, rich in thallium, whilst more prolonged heating causes the appearance of a second layer, composed mainly of the compound Bi_5Tl_3. The thickness of these two layers increases at higher temperatures at the expense of the original metals. The diffusion in this case is recognisable by means of the microscope after a year at atmospheric temperature. Lead and thallium behave similarly, as far as the evidence of heating curves goes, but a microscopical examination was not carried out. A determination of the electrical conductivity at different intervals shows that in this case also diffusion proceeds at a measurable rate at the ordinary temperature. The diffusion of tin into copper at 200°, and of zinc into copper at 400°, was also observed by more than one method.

The last-mentioned process, the diffusion of zinc into copper, lends itself well to microscopical observation on account of the formation of compounds differing in colour from the original metals. The superficial conversion of copper into brass by the action of zinc vapour has been known since the experiments of Spring, or even longer, and has been made the basis of a technical process.[68] The object to be coated is packed in zinc dust, mixed with zinc oxide or carbon to prevent caking, and heated at 250° to 300° in a rotating drum. The process has found a more extensive application in the coating of iron with zinc as a substitute for wet galvanising, and is known as 'Sherardising.' The zinc vapour unites with the metal (iron or copper) to form a superficial alloy, but the subsequent penetration of zinc into the interior takes place by true diffusion.

The manner in which diffusion takes place in such complex cases is conveniently studied by immersing a rod of copper in molten zinc and withdrawing it after a short time. An adherent layer of a white brittle alloy is formed, and microscopical examination of a transverse section shows that this is separated from the copper by an intermediate layer which is readily identified as the β constituent.[69] There is a sharp boundary between this layer and the unaltered copper. If the metal is heated for several hours at 700° and slowly cooled, it is found that zinc has diffused inwards, the white outer layer disappearing, whilst the zone of the β constituent has greatly increased in breadth, and has formed a new layer, composed of the α constituent, between it and the unchanged copper core.

The most recent, and in some respects the most satisfactory, experiments are those of G. Bruni and D. Meneghini.[70] These authors employed metals of high melting-point, which form solid solutions without chemical combination, and they followed the progress of the diffusion by means of the change in the electrical conductivity. A nickel wire, 0·5 mm. diameter, was coated electrolytically with copper until the increase of weight corresponded with 59 per cent. copper and 41 per cent. nickel. The compound wire was then heated to 1,000° in hydrogen, and the conductivity was determined from time to time.

68 S. Cowper-Coles, *Electrochem. and Metall.*, 1904, **3**, 828.

69 C. H. Desch, 'Metallography' (London, 1910), p. 221.

70 *Atti R. Accad. Lincei*, 1911 [v.], **20**, i. 671, 927; *Intern. Zeitsch. Metallographie*, 1912, **2**, 26.

A slight increase of conductivity was noticed in the first hour, owing to the conversion of electrolytic copper into the better-conducting annealed form, but after this a continuous decrease of conductivity was observed, the minimum being practically reached after 140 hours, when the value attained was exactly that of a homogeneous alloy of the same composition. Exactly similar results were obtained when gold wires were coated with silver or copper. In a further experiment the area of contact of the two metals was greatly increased by coating a copper wire, 0·075 mm diameter, with nickel and copper alternately, until thirty layers of each metal had been deposited. The thickness of the layers gradually diminished towards the outside, ultimately reaching a value of about 2·5 μ. Such a wire became homogeneous, as shown by microscopical examination as well as by the determination of the conductivity, after less than two hours at 1,000°, whilst diffusion proceeded at an appreciable rate at 500°. These authors are now engaged on experiments with still finer layers of the two metals, with the object of studying diffusion at still lower temperatures

The attempt has been made to draw a distinction between diffusion in metals and that in fluids on the ground that the penetration of oxygen into iron or steel in the ordinary process of tempering does not proceed indefinitely, but ceases at a certain finite depth, dependent only on the temperature [71] This is, however, inconsistent with the facts, as it is now known that the tempering colours, by which the thickness of the oxidised film is judged, are dependent on time as well as on temperature, and that although the diffusion of oxygen in such cases is slow, the process continues to greater and greater depths if given sufficient time.

Cementation and Decarburisation of Iron

The process of converting iron into steel by heating in contact with solid carbon has undoubtedly been practised from ancient times, although it is not described by ancient authors [72] The examination of early implements sometimes shows that the iron has been superficially hardened by this means For example, a Sinhalese chisel of the fifth century showed carburisation at the edge, the mass of the chisel being soft iron made by the direct process [73] It is suggested that the process is of Indian origin. An accurate description of cementation, as well as of the converse process of decarburising iron by heating in hæmatite, is given by R. A. F. de Réaumur.[74] As regards a theoretical explanation, the fact of reaction between solid substances was felt to be a difficulty, and an hypothesis was proposed, according to which the active cementing substance was not carbon, but gaseous hydrocarbons derived from impurities in the charcoal, or oxides of carbon.[75]

[71] C. Barus and V. Strouhal, *Bull. U.S. Geol. Surv.*, 1886, **27**, 51; C. Barus, *Nature*, 1889, **41**, 369.

[72] J. Percy, 'Metallurgy, Iron and Steel' (London, 1864), p. 110.

[73] Sir R. Hadfield, *Proc. Roy. Soc.*, 1912, **86***A*, 94; *Jour. Iron and Steel Inst.*, 1912, i.

[74] 'L'Art de convertir le fer forgé en acier, et l'art d'adoucir le fer fondu' (Paris, 1722).

[75] F. Le Play, *Ann. Chim. Phys.*, 1836 [ii.], **62**, 291; F. Le Play and A. Laurent, *ibid.*, 1837 [ii.], **65**, 403.

As, however, contact with a block of graphite was found to suffice when the iron was heated in a porcelain tube, the further assumption was made [76] that carbon vapour was formed under such conditions. This was the beginning of a controversy that has been renewed at intervals down to the present day. The views of Le Play and Laurent were opposed by Gay-Lussac, who, whilst admitting that much in the process of cementation is obscure, closes his vigorously written memoir [77] with the words:—

'Il n'est plus permis aujourd'hui d'avoir une foi aveugle au principe si banalement répété des anciens chimistes, *corpora non agunt nisi soluta* Il est certain, au contraire, que tous les corps, solides, liquides ou aériformes, agissent les uns sur les autres, mais que, des trois états des corps, l'état solide est le moins favorable à l'exercice de l'affinité '

The adoption of van't Hoff's view of the nature of solid solutions would reconcile Gay-Lussac's conclusion with the principle of the older chemists

The view that cementation is a process of true diffusion in the solid state was distinctly advanced by experiments which showed that the curve of distribution of carbon with depth at any given temperature had the form of a diffusion curve [78] The memoir of Mannesmann is particularly valuable for its mass of experimental evidence The form of the curve has since been redetermined with greater exactness,[79] confirming previous conclusions Mannesmann's experiments showed that under suitable conditions cementation only took place where the iron was actually in contact with solid carbon, whereas, if the active agent had been traces of gaseous compounds, the action should have been general, and not localised Charcoal always contains absorbed gases, which are removed only with difficulty, and special interest therefore attaches to experiments in which graphite or diamond is used in place of the amorphous modification. As far back as 1865 it had been shown [80] that iron was carburised by direct contact with either graphite or diamond in an atmosphere of hydrogen In such early investigations, however, no account was taken of oxides of carbon occluded in the iron, and the experiments have been repeated on many occasions by other observers, with contradictory results Thus it was found [81] that diamond would carburise iron at 1,160° in an atmosphere of nitrogen, and that the cementation was actually more rapid than when other modifications of carbon were used Similarly, the direct contact of diamond with iron in a vacuum, the degree of which is not stated, was found to bring about cementation.[82] On the other hand, it has been stated that the presence of gaseous compounds is necessary

[76] A. Laurent, *Ann Chim Phys* 1837 [II], **65**, 417.
[77] *Ann. Chim. Phys* , 1846 [III.], **17**, 221.
[78] R. Mannesmann, *Verh. Ver. Beförd. Gewerbefl.*, 1879, **58**, 31 ; A. Colson, *Compt rend.*, 1881, **93**, 1074.
[79] W. C. Roberts-Austen, *Jour. Iron and Steel Inst* , 1896, i. 139.
[80] F. Margueritte, *Ann. Chim. Phys.*, 1865 [IV.], **6**, 55.
[81] W. Hempel, *Ber.*, 1885, **18**, 998.
[82] W. C. Roberts-Austen, *Jour Iron and Steel Inst.*, 1890, i. 91.

before any penetration takes place [83] Certain precautions have to be taken to avoid errors in the interpretation of the results Thus, an experiment may fail from the absence of a satisfactory contact between the carbon and iron This may be ensured by the application of pressure, which accordingly favours cementation [84] On the other hand, in the course of experiments in which negative results were obtained from solid carbon and iron in a high vacuum, both materials being previously freed from gas, it was observed that a small reduction in the degree of the vacuum, caused by the admission of gas, led to carburisation [85]

A careful investigation, in which these conditions are taken into account, is due to F. Weyl [86] The materials used were sugar charcoal, purified by heating in chlorine and in hydrogen, natural graphite, the ash of which had been reduced to 0·22 per cent by treatment with sulphuric and hydrofluoric acids, 'kish,' or graphite obtained by stirring molten iron saturated with carbon, the ash being reduced to 0·82 per cent by successive treatment with nitric acid, chlorine, and hydrofluoric acid; and diamond Iron prepared in an electric furnace was used on account of its freedom from slag The polished cube of iron rested by one of its faces on the surface of the carbon A good vacuum was maintained, the pressure being always below 0 05 mm, and frequently as low as 0·001-0·002 mm throughout an experiment Positive results were obtained in all cases, whilst the supposition that gases played any important part in the transport of carbon was negatived by the observation that a layer of kaolin, 0 25 mm thick, interposed between the carbon and the iron, sufficed to prevent all cementation. The influence of contact was shown by the fact that very little cementation was obtained with fragments of diamond when the iron rested upon them, whereas when the diamond dust was placed on the upper surface of the iron cementation occurred quite readily In the latter case the finer particles of diamond came into contact with the iron, whilst in the former they were separated In view of these results it is not easy to understand the failure of Charpy and Bonnerot to obtain carburisation under similar conditions, unless the contact between the two substances in their experiments was insufficiently good

Graphite which is already present in the interior of a mass of iron is undoubtedly absorbed to a considerable extent on heating Thus, when grey iron is heated to different temperatures above 700° and quenched, the proportion of combined carbon is increased, the quantity increasing rapidly with the temperature [87] A similar observation has been made in respect to temper carbon, which is finely divided graphite [88]

Mention must now be made of a class of experiments in which the

[83] L. Guillet, *Rev. de Métallurgie*, 1906, **3**, 227.
[84] L. Guillet and C. Griffiths, *Compt. rend.*, 1909, **149**, 125.
[85] G. Charpy and S. Bonnerot, *ibid.*, 1910, **150**, 173.
[86] *Métallurgie*, 1910, **7**, 440.
[87] G. Charpy, *Compt. rend.*, 1907, **145**, 1277.
[88] H. Le Chatelier, *Rev. de Métallurgie.*

carbon is not used in the free state, but in the form of a steel rich in carbon. If the process be one of true diffusion, carbon should tend to pass from places of high to those of low concentration. This is found to be the case When two pieces of steel, containing respectively 0·90 per cent and 0·15 per cent. of carbon, are placed in immediate contact and heated, air being excluded, carbon passes from the high into the low carbon steel, the gain of weight of the one being almost exactly equal to the loss of weight of the other [89] Experiments on this point have been made with great care, a cylinder of nearly pure iron being bored through longitudinally, and fitted over a core of steel containing a much larger proportion of carbon.[90] After heating for ten hours *in vacuo* at 950° to 1,050° the outer jacket was turned off, and the layer immediately adjoining the core was analysed The diffusion of carbon was clearly proved in this manner.

The fact that the materials used in the practical cementation of iron are commonly not pure carbon, but contain combined nitrogen, has led on several occasions to the supposition that the carbon diffuses in the form of a compound of nitrogen, such as cyanogen, or that a nitride of iron takes part in the process, as well as the carbide. The cyanogen theory is due to W Stein,[91] but need not be further considered here, as there is no reason to suppose that nitrogen is responsible for the transport of carbon within the metal, whatever may be the case in regard to the formation of the external layer of highly carburised iron. It is certain that the presence of cyanides and of gaseous carbon compounds greatly accelerates diffusion, but it does not follow that the process of diffusion into the interior differs in any respect from that which occurs when elementary carbon is the cementing agent [92] Very rapid cementation is brought about by the action of mixtures of the oxides of carbon on iron,[93] especially when the mixture in equilibrium with solid carbon at the required temperature is used It is not necessary to assume that the gases penetrate to the interior of the metal and so convey the carbon; on the contrary, the experiments support the view that the function of the gas is merely that of reacting with the iron to form a superficial layer rich in carbon, from which diffusion inwards can then proceed. The investigations of Arnold and McWilliam and of others have clearly established the fact that the carbon does not diffuse in the free state, but as a carbide, Fe_3C, although the further assumption by the above-named authors, that an intermediate carbide, $Fe_{24}C$, is formed, has not met with general acceptance

As the carbide is not appreciably soluble in α-iron it is to be expected that cementation should not take place below 690°, the lowest temperature at which austenite, the solid solution of carbide in γ-iron, can exist in a stable state, and this appears to be generally true,

[89] G. P. Royston, *Jour. Iron. and Steel Inst.*, 1897, i. 166.
[90] J. O. Arnold and A. McWilliam, *ibid.*, 1899, i. 85
[91] *Polyt. Centr.*, 1851, 897.
[92] A. Ledebur, *Stahl und Eisen*, 1906, 26, 72.
[93] F. Giolitti, *Jour. Iron and Steel Inst.*, 1911, ii. 307; summarising a series of papers contained in *Gazzetta*, 1910–1911.

although cementation to a very slight extent at so low a temperature as 250° has been recorded.[94]

The diffusion of silicon into iron has often been observed.[95] At 1,200° it is possible to convert iron completely into a silicide by heating in contact with solid silicon, although in this instance the vapour of silicon has been considered to play a part in the reaction.[96] The difficulty of observations of this kind is illustrated by the case of sulphur. An attempt to measure the diffusion of sulphides through steel led at first to very inconclusive results,[97] owing to the escape of fusible sulphides, but further experiments showed that true diffusion took place, and that when cuprous sulphide was used a part of the copper was also transported into the metal.[98]

When iron was placed in contact with alloys of iron containing other elements and heated at about 1,000° *in vacuo*, diffusion was observed when the element studied was sulphur, phosphorus, or nickel, but not when it was manganese, silicon, chromium, aluminium, tungsten, arsenic, or copper.[99]

The case-hardening of iron and steel is a process of superficial cementation, and what has been said as to the latter process applies also to the former. Many important details as to the velocity of carburisation and diffusion are to be found in Giolitti's memoirs.

The decarburisation of iron-carbon alloys by heating in an oxidising medium is the reverse of cementation. Oxides of iron are commonly employed as the medium. The process was described in detail by Réaumur.[100] It is known that the removal of the carbon is preceded or accompanied by the decomposition of the carbide into iron and temper carbon, and the reaction has been explained[101] as one of oxidation of this free carbon by carbon dioxide, formed by reactions between the oxidising material and the carbide in the superficial layer of iron. The explanation is, however, imperfect, and it is certainly possible for carbon to be removed without previous precipitation as temper carbon.[102] It is therefore most probable that removal of carbon by true diffusion actually takes place, in accordance with the theory formerly held, and that decarburisation by gas, although taking the principal share in some forms of the technical process, is not absolutely essential.

Segregation and Recrystallisation

Diffusion in solid metallic alloys is well illustrated by the segregation of constituents. A new phase commonly makes its first appearance in a finely divided form, and although chemical equilibrium may have been attained, physical equilibrium is not reached until the small particles have united to form larger aggregates. Steel offers a good

[94] A. Colson, *Compt. rend.*, 1881, **93**, 1074.
[95] A. Colson, *ibid.*, 1882, **94**, 26.
[96] H. Moissan, *ibid.*, 1895, **121**, 621; P. Lebeau, *Bull. Soc. Chim.*, 1902 [iii.], **27**, 44.
[97] E. D. Campbell, *Jour. Iron and Steel Inst.*, 1897, ii. 80.
[98] *Ibid.*, 1898, ii. 256; S. A. Grayson, *ibid.*, 1910, i. 287.
[99] J. O. Arnold and A. McWilliam, *loc. cit.* [100] *Op. cit.*
[101] F. Wüst, *Metallurgie*, 1908, **5**, 7; H. Becker, *ibid.*, 1910, **7**, 41.
[102] W. H. Hatfield, *Jour. Iron and Steel Inst.*, 1909, i.

example of this. The carbide separating from solid solution during cooling is at first in a state of ultramicroscopic division, and troostite has been described as a solid colloidal solution of carbide in iron.[103] If more slowly cooled, finely granular sorbite and laminated pearlite are successively obtained. Pearlite has been commonly regarded as the normal form of the eutectoid, but it is found that further heating causes the laminæ to contract, producing beaded forms,[104] and ultimately the carbide segregates into coarse masses,[105] so that the steel presents the paradoxical condition of containing both structurally free iron and carbide.[106]

The dispersion of a newly formed solid phase in an ultramicroscopic form through a crystalline mass of metal is not uncommon [107] It is observed in alloys of nickel and iron, of cadmium and tin,[108] and also in the β solid solution of copper and zinc.[109] This last case is of special interest The β solution is not stable below 475°, at which temperature it is resolved into a mixture of the α and γ phases, which at first remain in a state of ultramicroscopic division Segregation is extremely slow, even at temperatures only slightly below the transformation point, but is accelerated by the presence of the α or the γ phase in excess, or by the presence of a third metal in solid solution, such as aluminium.

When crystals of a solid solution separate from a liquid, the composition of the crystals is only uniform if the rate of cooling is so slow that time is allowed for continual readjustment of equilibrium between the solid and liquid phases by diffusion within the solid. If this is not the case, the crystals have a zonal structure, the outer zones being relatively richer than the inner in that component which lowers the freezing-point Such zonal or 'cored' structures are usually present in solid solutions of metals cooled under ordinary conditions. Although it has been attempted to explain these structures as produced by purely mechanical causes,[110] there is no doubt that the difference between adjoining zones is a chemical one, as is shown by the behaviour of the crystals on etching It can be shown in an effective manner by immersing a specimen of a tin bronze, for example, in a solution of copper sulphate, when metallic copper is deposited only on those zones which are richest in tin.[111]

When such an alloy is annealed at a temperature well below the melting-point diffusion takes place, and the composition of the crystals becomes uniform. This process is easily observed by means of the microscope The cores in an α solid solution of tin in copper disappear when the alloy is heated to 750° for three hours,[112] and the time required in other cases is very similar.

103 C. Benedicks, *Jour. Iron and Steel Inst*, 1905, ii. 352; 1908, ii. 217.
104 C. Benedicks, *Metallurgie*, 1909, **6**, 567.
105 J. E. Stead, *Jour. Soc Chem. Ind*, 1903, **22**, 340.
106 E. F. Lange, *Metallographist*, 1903, **6**, 9.
107 C. Benedicks, *Zeitsch. Chem. Ind. Kolloide*, 1910, **7**, 290
108 W. Guertler, *Intern. Zeitsch. Metallographie*, 1912, **2**, 172
109 H. C. H. Carpenter, *Jour. Inst. Metals*, 1912, **7**, 123.
110 F. Osmond and G Cartaud, *Compt rend*, 1904, **139**, 404.
111 F. Giolitti, *Gazzetta*, 1908, **38**, ii. 352.
112 A. Portevin, *Rev. de Métallurgie*, 1909, **6**, 813.

In alloys which contain two solid solutions in equilibrium with one another, such as the $\alpha\beta$ alloys of copper and zinc, the structure also becomes coarser when the alloys are heated at a temperature at which diffusion takes place

The increase in size of crystals is equally pronounced when only a single constituent—a pure metal or a solid solution—is present The growth of the ferrite grains in soft steel at 700°-720° is extremely rapid,[113] and the process may be very conveniently studied in such a solid solution as 70 30 brass.[114] The growth of crystals may be watched in lead even at 60° if the metal has been previously strained [115] It is always the larger crystals that absorb the smaller.

Whether the metal in which such recrystallisation takes place is homogeneous or heterogeneous, diffusion must occur in order that the rearrangement may come about The effect has been explained by the principle that small crystals have a greater solubility than large, so that if small and large crystals of the same substance are both in presence of a solvent, solution and re-deposition tend to go on [116] until only crystals above a certain size are present. This has been verified for the case of calcium sulphate in water.[117] A thermo-dynamical explanation has also been given [118] of the principle that the bounding surface between a crystal and its saturated solution tends to become a minimum, so that equilibrium is only finally reached when all the small crystals have united to form a single crystal

The principle of differing solubility is rejected as an explanation by G Tammann,[119] who assumes that the surface tension, which is less than the forces producing rigidity in a crystal at the ordinary temperature, may become much more considerable with increase of temperature When the surface tension exceeds the opposing forces, two crystals unite as two drops of fluid would do The hypothesis is ingeniously applied to explain the recrystallisation of strained metals

The Influence of the Amorphous Modification in Metals

The view has been taken [120] that the occurrence of diffusion in heated metals is not a proof that diffusion may occur in a crystalline medium, as Spring's experiments have rendered the presence of amorphous material in metals extremely probable Since then the existence of an amorphous modification in worked metals has been proved by much experimental work,[121] but it has also been shown that complete recrystallisation occurs at very moderate temperatures, such as 250° for copper and 300° for silver [122]

113 J. E. Stead, *Jour. Iron and Steel Inst.*, 1898, i. 145; A. Joisten, *Metallurgie*, 1910, **7**, 456.

114 G. Charpy, 'Etude des Alliages' (Paris, 1901), p. 1.

115 J. C. W. Humfrey, *Phil. Trans.*, 1902, **200**A, 225.

116 W. Ostwald, *Zeitsch. Physikal. Chem.*, 1900, **34**, 495.

117 G. A. Hulett, *Zeitsch. Physikal. Chem.*, 1901, **37**, 385.

118 J. Curie, *Bull. Soc. Franc. Min.*, 1885, **8**, 145.

119 *Nachr. K. Ges. Wiss. Göttingen*, 1912, 1.

120 G. Bodlander, *N. Jahrb. Min. Beil. Bd*, 1899, **12**, 52.

121 G. T. Beilby, *Phil. Mag.*, 1904 [vi.], **8**, 258.

122 G. T. Beilby, *Jour. Inst. Metals*, 1911, **6**, 5.

Recently, on the grounds of the behaviour of worked and unworked metals when subjected to tensile stresses at high temperatures, the hypothesis has been proposed [123] that a small quantity of the amorphous modification persists to much higher temperatures, the 'temperature of complete recuperation' being fixed at 650° for copper and 710° for an alloy of copper and nickel Even this modified hypothesis, however, only assumes the presence of a small quantity of intercrystalline material in the amorphous state, and the phenomena observed are in no way to be explained by diffusion through these small masses. An argument against diffusion in crystals is not, therefore, to be based on the existence of amorphous modifications of metals.

The Electrolysis of Crystalline Solids.

The electrical conductivity of metallic sulphides has repeatedly been the object of study, and it was shown by W. Hittorf [124] that the conductivity of silver and cuprous sulphides was electrolytic in character The conductivity of most sulphides is, however, metallic. The electrolysis of natural quartz crystals was observed by E. Warburg and F. Tegetmeier,[125] and it was found that electrolysis was only obtained in the direction of the principal axis. The actual electrolyte is the alkali silicate always present in natural quartz. Further investigations show that the conductivity of sulphides is more electrolytic at high temperatures and metallic at low temperatures,[126] whilst pure oxides of most metals conduct almost exclusively metallically [127] Elaborate investigations of a large number of compounds show that whilst electrolysis undoubtedly occurs, it is the exception rather than the rule, and that solid electrolytes are usually of a saline character.[128]

Special attention has been given to the conductivity of the mixtures of rare earth oxides used in the Nernst filament These are regarded as electrolytes conveying an unusually large residual current.[129] It is possible that these masses are not entirely crystalline.

Solid barium chloride is an electrolyte, obeying Faraday's law,[130] whilst sodium hydroxide presents anomalies, indicating that at 230° traces of a liquid substance are present in the pores Porcelain, which is only in part crystalline, is an electrolyte from 300° upwards, its behaviour being that of a solution of alkali silicates in aluminium silicate as a non-conducting solvent [131]

Special interest attaches to the crystallised silver halides Their conductivity in the solid state was investigated by F. Kohlrausch [132] It was then found [133] that solid silver iodide is an electrolyte, and that

[123] G. D. Bengough, *Jour. Inst. Metals*, 1912, **7**, 123.
[124] *Pogg. Ann.*, 1851 [iii.], **24**, 1.
[125] *Ann. Physik.*, 1888 [ii.], **35**, 455.
[126] R. von Hasslinger, *Monatsh.*, 1907, **28**, 239.
[127] F. Horton, *Phil. Mag.*, 1906 [vi.], **11**, 505.
[128] J. Koenigsberger, *Zeitsch. Elektrochem.*, 1909, **15**, 97; C. Doelter, *ibid.*, 1908 **14**, 552; *Monatsh.*, 1910, **31**, 493.
[129] W. Nernst, *Zeitsch Elektrochem.*, 1899, **6**, 41; 1900, **7**, 373.
[130] F. Haber and S. Tolloczko, *Zeitsch. Anorg. Chem.*, 1904, **41**, 407.
[131] F. Haber, *ibid.*, 1908, **57**, 154.
[132] *Ann. Physik.*, 1882 [ii.], **17**, 642.
[133] O. Lehmann, *ibid.*, 1889 [ii.], **38**, 396.

films and threads of metallic silver make their appearance when a current is passed through a crystal under the microscope Great weight is to be attached to microscopical investigations of this kind. Thus, it was found that solid silver chloride remained unchanged in appearance, and no polarisation could be observed when a current was passed through it, although the resistance diminished in a remarkable manner,[134] but subsequent examination [135] proved that the increased conductivity was due to microscopic filaments of metallic silver.

Metallic alloys do not conduct electrolytically. A series of experiments in which two cylinders of different metals were placed in close contact, a current being passed, showed that no transport of matter took place, even when considerable currents were used [136] This is entirely in accordance with older observations An isolated result, that carbon could be caused to travel with the current in steel,[137] is probably susceptible of another explanation

Diffusion in Minerals

The question whether true solid diffusion ever occurs in minerals is very difficult to answer The term 'diffusion' has sometimes been employed rather loosely in geological writings, so that a complex rock such as granite has been spoken of as diffusing into surrounding schists, a comparison being made with Roberts-Austen's experiments with metals [138] In such a case the action is evidently one of mechanical percolation The most favourable instances might be expected to be the secondary replacement of minerals and the formation of pseudomorphs Attention has been drawn to the fact that whilst certain alterations, such as the conversion of olivine into serpentine, obviously proceed along cracks in the original crystal, other changes are of a much finer character, and must be assumed to depend on a molecular porosity [139] The writer has not, however, been able to find, from the examination of photo-micrographs and of rock-sections, that any cases of alteration can be attributed unhesitatingly to diffusion, as even when cracks are absent the alteration very commonly proceeds along cleavage planes It is possible, but by no means certain, that such reactions proceed by true diffusion

It has been urged as a fatal objection to the occurrence of solid diffusion in crystalline substances that crystals of native minerals are found in which successive zones of minerals known to be isomorphous with one another are in intimate contact, and yet there is no indication of inter-diffusion having taken place, although geological ages have elapsed since the crystals have been deposited from a fluid magma. Augite and the triclinic felspars often exhibit zonal structures in great perfection. In the case of metals, as described above (p 353), zonal structures occur when the rate of cooling of a liquid depositing crystals

[134] M. Le Blanc and F. Kerschbaum, *Zeitsch. Elektrochem*, 1910, **16** 242.
[135] *Ibid.*, **680.**
[136] J. Kinsky, *Zeitsch. Elektrochem.*, 1908, **4**, 406.
[137] J. Garnier, *Compt. rend.*, 1893, **116**, 1449.
[138] E. Greenly, *Geol. Mag*, 1903 [iv.], **10**, 207.
[139] C. A. McMahon, *Brit. Assoc. Reports*, 1902, 589

of a solid solution is too great to allow of equalisation of the solid solution by diffusion in order to re-establish equilibrium Annealing at a temperature below the solidus curve favours diffusion, and usually brings about equalisation in a short time, measurable in hours.

The best zonal structures are obtained when the two end-members of the series composing the crystal have nearly identical molecular volumes, as in the triclinic felspars, in which the variation is only from albite, 100·13, to anorthite, 101·49.[140]

The most favourable instances for the view that reactions involving diffusion may take place within a crystalline mineral are those of schiller-inclusions, as of magnetite in the olivine from peridotite, Isle of Rum,[141] and in the hypersthene from norite, Labrador, and also of rutile in certain felspars and pyroxenes Such structures may well be due to the change in concentration of a solid solution during cooling causing the separation of the constituent in excess. The microperthitic intergrowths of albite and orthoclase in alkali-granite (Rockport, Mass) and of albite and microcline in nepheline-syenite (Miask, Ural) are also instanced by Harker as being very possibly formed in the solid state These structures are strongly suggestive of the eutectoids of certain metallic alloys. 'Pyroxene-perthite,' an intergrowth of rhombic pyroxene and diopside, suggests a similar origin [142]

Agate and chalcedony are to be classed among solid colloids rather than among crystalline minerals, but the suggestion that certain brecciated and banded structures observed in them are not of primary origin, but have arisen through segregation in the solid state,[143] should not be overlooked

Finally, in this connection, mention may be made of the 'pleochroic halos' observed in certain minerals, notably biotite, and attributed to the α radiation from minute enclosures of radioactive material Each halo is made up of several concentric shells, each of which represents the range of some of the types of α particle emitted.[144] Halos in all stages of development have been observed Artificial pleochroic halos have been obtained in glass [145] The origin of the halo is of course not ordinary diffusion, as the α particles are shot off at great speed from the centre, but the penetration of the crystalline material appears certain

Diffusion in Artificial Crystals

The process of diffusion in crystalline salts or organic substances has been little studied From the fact that isomorphous crystals frequently resolve themselves into their components on cooling, and that other crystals unite under similar conditions, it is certain that diffusion must take place, but there is usually no record of direct

140 T. V. Barker, *Trans. Chem. Soc.*, 1906, **89**, 1120.

141 A. Harker, 'The Natural History of Igneous Rocks,' p. 257.

142 J. H. L. Vogt, *Tscherm. Min. Mitt.*, 1905 [ii.], **24**, 537.

143 J. Ruskin, *Geol. Mag.*, 1867–1870, **4–7**; reprinted in 'Collected Works,' vol. **26**, pp. 36 ff.

144 J. Joly, *Phil. Mag.*, 1907 [vi.], **13**, 381; J. Joly and A. L. Fletcher, *ibid.*, 1910 [vi.], **19**, 630.

145 E. Rutherford, *Mem. Manchester Phil. Soc.* 1909, **54**, v. 1.

observation of this kind. It has, however, been observed that mixtures of 80 to 93 per cent of ammonium nitrate and 20 to 7 per cent. of potassium nitrate, which solidify to form a mixture of two saturated solid solutions, become turbid on cooling past 104°, and monoclinic crystals then appear, which gradually absorb both the original forms, the mass ultimately becoming homogeneous. In some cases the resulting crystals are optically perfect, whilst in others traces of heterogeneity remain.[146]

The other case is more frequent. An instance described in the above memoir is that of mixtures of 67 per cent of ammonium nitrate with 33 per cent. of cæsium nitrate. These mixtures solidify to form homogeneous cubic crystals, which become rhombohedral at a lower temperature. On cooling still further, these crystals are resolved into two distinct kinds of crystals, respectively isomorphous with the two components.

It will be sufficient to cite one other example among salts. Mixtures of sodium sulphate and potassium sulphate solidify in the form of homogeneous crystals throughout the whole range of composition, but at lower temperatures separation into the double salt, Na_2SO_4,K_2SO_4, and the excess of one or the other constituent takes place.[147]

An interesting case of dissociation in, and crystallisation from, a solid solution has been observed in the case of *o*-nitrobenzaldehyde, which is converted into *o*-nitrosobenzoic acid in sunlight. The green unimolecular modification of the nitroso-compound is produced as long as it remains in a state of solid solution, but when this becomes saturated the nitroso-compound formed subsequently separates in crystals of the white bimolecular modification.[148]

It does not appear that diffusion has been observed in the case of zonal crystals of salts or organic compounds, although such crystals are readily prepared by allowing a salt to grow in a saturated solution of an isomorphous salt, and similar crystals have been frequently investigated on account of the optical anomalies that they present. Very remarkable results have been obtained, however, by the examination of crystals which have absorbed a colouring matter, not isomorphous with the substance examined, during crystallisation. These crystals commonly present optical anomalies, and the distribution of the colouring matter is frequently not uniform, but is confined to certain zones or sectors. In some cases the anomaly is undoubtedly due to mechanical strain caused by the interposition of a foreign material in the mass of the crystal, as the same effect is observed in crystals built up of isomorphous salts,[149] but in other cases the disturbance goes further than this. Without referring to the very voluminous literature of this subject, a few typical examples may be mentioned. Experiments with 33 inorganic salts and 26 colouring matters, mostly aniline dyes,

[146] F. Wallerant, *Compt. rend.*, 1906, **142**, 100.
[147] R. Nacken, *N. Jahrb. Min. Beil. Bd.*, 1907, **24**, 1.
[148] C. A. Lobry de Bruyn and C. L. Jungius, *Proc. k. Akad. Wetensch. Amsterdam.*, 1903, **5**, 643.
[149] A review of the subject to 1891 is given by R. Brauns, 'Die optischen Anomalien der Krystalle' (Leipzig, 1891).

only resulted in stained crystals in four instances.[150] The nitrates of the barium group may be stained with methylene blue, these being perhaps the most successful instances of the kind.[151] Potassium iodide crystals absorb iodine vapour, and the salt separates in coloured crystals from solutions containing iodine, but microscopical examination shows that the distribution within the crystal is very far from uniform.[152]

Somewhat more exhaustive experiments have been made with meconic acid. Crystals of this acid may be stained if allowed to crystallise from solutions containing 'Fettfarben,' but if the colourless crystals are placed in a solution of the dye the colour is not absorbed[153] It was objected[154] that the experiment was only conclusive if it were also shown that the same solvent (benzene or light petroleum) did not extract the dye from previously stained crystals This proved to be the case,[155] and the evidence therefore shows that in this instance diffusion of the colouring matter does not occur, even when the conditions are apparently favourable

Diffusion in Colloidal Gels

The diffusion of salts in gels, such as gelatin, agar-agar, and colloidal silica, differs little from the same process in water, the diffusion following the same laws, and the velocity being diminished to a comparatively small extent This was first studied by T Graham,[156] and confirmed in detail by F. Voigtlander[157] The velocity diminishes with increasing concentration of the colloid,[158] and is also influenced by the presence of foreign substances

Liesegang's Phenomenon

An interesting phenomenon, which is of importance for the theory of diffusion in many cases, was first observed by R E Liesegang[159] In the most convenient manner of conducting the experiment, a thin layer of gelatin, spread on a glass plate, is impregnated with potassium dichromate and allowed to dry A drop of silver nitrate solution is then placed on the gelatin surface As the solution diffuses outwards silver chromate is precipitated, but instead of forming a ring round the original spot, diminishing steadily in intensity towards the circumference, the silver chromate is deposited intermittently, forming a series of concentric rings, which under favourable conditions are of very remarkable regularity Many other salts behave in the same way as silver chromate It is not even necessary that a precipitate be formed, as similar rings may be obtained by the diffusion of a single

150 J. W. Retgers, *Zeitsch Physikal. Chem*, 1894, **12**, 583.
151 P. Gaubert, *Bull. Soc Franç Min.*, 1901, **23**, 211.
152 E. Sommerfeld, *N Jahrb. Min*, 1902, ii 43
153 O. Lehmann, *Ann. Physik*, 1894 [iii.], **51**, 47
154 W. Ostwald, *Zeitsch. Physikal. Chem.*, 1894, **13**, 758.
155 S. Ružička, *ibid*, 1910, **72**, 381.
156 *Phil. Trans.*, 1866, **156**, 399
157 *Zeitsch Physikal. Chem*, 1889, **3**, 316.
158 K. Meyer, *Beitr. Chem. Physiol. Path.*, 1905, **7**, 393; H. Bechhold and J. Ziegler, *Zeitsch. Physikal. Chem.*, 1906, **56**, 105.
159 'Chemische Reaktionen in Gallerten' (Dusseldorf, 1898); 'Ueber die Schichtungen bei Diffusionen' (Leipzig, 1907).

salt, such as sodium phosphate,[160] or by the hydrolysis of a chromium salt [161] Each ring is formed suddenly, and the distances between successive rings follow a definite law An explanation of the phenomenon was suggested by W Ostwald,[162] who attributed the formation of rings to supersaturation On this view, the silver chromate at first formed remains in the form of a supersaturated solution in the gelatin until the metastable limit of concentration is passed A ring is then formed, and the chromate in the immediate neighbourhood is attracted to that already deposited The silver solution continues to diffuse, passing over a space which is practically devoid of chromate, until a new formation takes place, and the process is repeated This hypothesis leads to quantitative results in agreement with those observed, and it is possible to calculate the metastable concentration product, a quantity resembling the 'solubility product' for compounds precipitated from solution [163] The fact that two systems of rings, formed at different times in the same film of gelatin, can cross one another without interference [164] seemed opposed to the explanation, until it was shown [165] that the two systems are not in the same plane, and therefore do not come into actual contact A more serious objection is that if the gelatin be previously impregnated with lead iodide and potassium iodide, so that abundant minute crystals are formed, on the addition of a drop of lead nitrate solution Liesegang's rings may still be obtained in the film, although the formation of supersaturated solutions would seem to be impossible [166] Other explanations have been proposed, based on the influence of the excess of soluble salt present,[167] or on the difference in velocity of the two diffusing salts,[168] but it does not appear that either hypothesis will account for the whole of the facts [169]

Liesegang's phenomenon has been recently invoked [170] to explain the structure of agates by the diffusion of an iron salt into a silica gel, and it has been found possible to imitate very closely the banded structures of agates by impregnating masses of gelatin with salts and allowing other salts to diffuse inwards

Conclusion

The foregoing account does not pretend to anything like completeness The number of investigations—physical, chemical, metallurgical, and geological—bearing on this subject is extraordinarily large, but the selection given may serve to show the lines of argument The older view that solid solutions have no existence among crystalline substances,

160 R. E. Liesegang, *Zeitsch. Physikal Chem*, 1910 **75**, 371
161 H R Procter and D J Law, *Jour. Soc Chem. Ind*, 1909, **28**, 297
162 *Zeitsch. Physikal. Chem*, 1897, **23**, 365
163 H. W. Morse and G W. Pierce, *Zeitsch. Physikal. Chem*, 1903, **45**, 589.
164 R. E Liesegang, *ibid.*, 1907, **59**, 444 165 *Ibid*, 1910, **75**, 371.
166 E. Hatschek, *Zeitsch. Chem Ind. Kolloide*, 1912, **10**, 124.
167 H Bechhold, *Zeitsch. Physikal. Chem*, 1905, **52**, 185.
168 E. Hatschek, *Zeitsch. Chem. Ind. Kolloide*, 1911, **9**, 97.
169 See also, for many important experiments on this subject, J. Hausmann, *Zeitsch. Anorg. Chem*, 1904, **40**, 110.
170 R. E. Liesegang, *Centr. Min.*, 1910, 593; 1911, 505; *Zeitsch. Chem. Ind. Kolloide*, 1911, **9**, 296.

and that isomorphous crystals have a minutely heterogeneous or zonal structure,[171] has been recently revived in respect to metallic alloys,[172] a department in which the conception of crystalline solid solutions has proved most fruitful A decision as to the conditions under which diffusion occurs in solids is of the highest importance in relation to this question A review of the evidence leads to the conclusion that the occurrence of diffusion in metals is established beyond any doubt, but that experiments are still lacking to prove its occurrence in transparent crystals of minerals, salts, or organic substances, even under favourable conditions, although even here indirect evidence points to its possibility The subject is complicated by the occurrence of adsorption, and it is sometimes difficult to separate the effects of adsorption from those of diffusion, but it seems an exaggeration to suggest [173] that the passage of metals into one another, forming easily recognisable intermetallic compounds, should be ascribed to adsorption, although such an explanation may possibly suffice in such cases as the passage of gases through heated metals, and the staining of transparent crystals

[171] See the reviews of the subject by O Lehmann, 'Molekularphysik' (1888), and, from an altered standpoint, 'Flüssige Krystalle' (1904)

[172] C A Edwards, *Jour. Inst Metals*, 1911, **5**, 150, **6**, 259, P P von Weimarn, *Zeitsch. Chem Ind Kolloide*, 1911, **9**,

[173] G. Bodländer, *N Jahrb Min. Beil Bd*, 1899 **12** 53.

The Road Problem *By* the Right Hon. Sir J. H. A MACDONALD, *K.C.B , F.R.S , Member of H.M. Road Board.*

[Ordered by the General Committee to be printed *in extenso*]

THE present year is probably the first in the world's history in which any national scientific association has condescended to allow the road to take a place in its syllabus In the early part of the present year the Royal Institution gave a welcome to a paper on the Past, Present, and Future of the Road, and the members accorded an appreciative reception to it Now, those who guide the proceedings of the British Association have asked that the subject should be dealt with by me, as a member of His Majesty's Road Board, and it is a pleasure to respond For there is nothing which that Board are more anxious to see than that an interest should be taken by the public in the improvement of roads, and that information regarding the work should be disseminated throughout the community Those who have studied the matter are forced to the conclusion that want of attention to efficient road construction causes a national loss annually of millions of pounds sterling There is vast loss in the wearing-out of traction animals and vehicles by the rough, uneven surface presented by our highways, made heavy by mud, and injurious to men and horses by dust There is vast loss by injury to goods by the dust which penetrates every package of goods which is not hermetically sealed, and forces its way into our shops and houses There is vast loss in the incapacity of the road user to cover any but the most limited distances by his horsed vehicles during the day's work There is vast loss from the insanitary conditions consequent upon the uncleanly state of the highway from the surfaces being such that insanitary matter not only lies upon them but lodges in them, and spreads mischief when it is dried into dust and blown into throats and into dwellings, carrying with it the seeds of disease, causing injury to health and even loss of life There is vast loss in the expense caused by the filthy condition of the streets of our towns, such a town as London or even Dundee having to do scavenging upon such a scale that thousands upon thousands of tons of filthy insanitary matter have to be removed from the streets annually In passing, I may mention as showing the greatness of this evil, and its diminution by the decrease in the number of horses—amounting in London already to at least 75 per cent —that in the City of Westminster alone the amount of street filth to be removed has during the last five years diminished by 18,000 tons per annum

The making of a road did not interest man in early times In the only two cases known in history where road-construction was systematically done, it was the military conqueror who did the work When the Roman invaded our land he, to facilitate the movement

of his troops, constructed roads over long stretches of country, which do credit to this day to the skill of his engineers They were, in fact, streets, well-bottomed, well-laid, well-drained, and well-paved The other case of real road-making in Scotland occurred in the time when the difficult work of finally quelling the resistance of the supporters of the Stuart dynasty in the Highlands was being carried on by a General who discerned the advantages to his work of good roads for moving his troops and their munitions of war So valuable was the work he had done to the good of the country that in later years an obelisk was erected in Inverness-shire in his honour, on which was carved as good a bull as ever was perpetrated in Ireland It read thus —

> If you had seen this road before it was made
> You would hold up both hands and bless General Wade

With the above exception the roads were in early times made by the traffic Those on foot wore down a path by pressure of the feet Those on horseback followed in the same tortuous line, avoiding obstacles No laws were passed till within the last two centuries to cause road construction, with one exception, and that was an ancient statute which ordained that:—

'Where any highway is worn deep and incommodious another shall be laid out alongside,' which meant not that a road should be really made, but only that large stones and bushes should be cleared away at the side of the road to open a new track The course of the road was made more tortuous than before, and this accounts for many of the curious windings of our roads even at this day

The roads being mere tracks their condition at all times was dreadful Queen Elizabeth, after taking her first drive in a regal coach obtained for her in France, complained to the French Ambassador that 'her body was full of aches and pains for days' after a two-hours' ride, in which probably she traversed about five miles Much later things were no better Young, a great traveller, writing in 1770, speaking of the North road, tells of 'ruts which measured four feet deep and floating in mud The only mending it receives is the tumbling in of some loose stones . jolting a carriage most abominably ' So frightful was the state of things that in seventy years in the eighteenth century 530 Acts of Parliament were passed, ordering the citizens to do work on the roads, they being required to give six days' labour annually or to pay a commutation sum of money But the work was done on no system and in great degree scamped, and the commutation money squandered and too often pilfered It may give an idea of the state of things to quote what Sir Henry Verney said in the House of Commons 'If a man were to propose to convey us regularly in coaches to Edinburgh in seven days should we not vote him to Bedlam? '

Practical science was applied for the first time to the road when Macadam and Telford came upon the scene. As Macadam said before a Committee of the House of Commons, the state of things which existed was chaotic, the road commissioners being appointed in absurd numbers for small areas—' thus a business of art and science is com-

mitted to a promiscuous mob of peers, squires, farmers, and shop-keepers who are not chosen for their fitness to discharge their duties,' and consequently the appointment of surveyor was in nineteen cases out of twenty ' a perfect job,' the appointment being too often given to a worthy man who was needy—having been a failure at everything else

Both Macadam and Telford made their road-crust of small stones broken to sharp angles and consolidated by pressure But being both Scotsmen they would not give something for nothing They called on the road user to bring the stones to a level by the tamping of the horse and the rolling of the wheels, placing trestles alternately on each side of the road so as to compel the user to take a zigzag course, and thus preventing longitudinal ruts being formed When one half of the zigzag was forced down to flatness the trestles were transferred across, and the work of forming the surface performed by the traffic over the other half The forming took some time, but as the traffic was at that time all by road the time was not unreasonable, and the result was a fairly good road, which threw off the water as long as it was kept in proper repair

But a few years later the railroad was adopted for all distance journeys, and the road was for many years more or less neglected, 90 per cent of the traffic formerly available for rolling the road being removed It thus became impossible to conduct road-making by putting down a heavy bed of loose stones, and leaving it to the road user to tamp and roll in the stones to a level The operation took so long as to cause the road to be highly injurious to animals and vehicles Accordingly, the heavy horse-roller, followed by the steam-roller, was introduced, saving the road-user from the weary work of making his own road But the steam-roller has not been an unmixed blessing Crushing down with its great weight, it flattened the road in one operation, with the result that interstices were left between the stones, into which water could pass down into and through the crust to the certain destruction of the road Accordingly, a device had to be resorted to that the spaces between the stones might be closed by added packing, and this has been done by making what can only be described as a soup of dirt and water and pouring it upon the stones and brushing and rolling this liquid mud into the crust of the road The road thus when opened for use is crusted with a coating of stones whose only binding is water thickened with dirt, or perhaps dirt diluted with water is the proper description The result is that it can never be a good road in wet weather, and can never be a good road in dry weather As long as it is in a slightly damp state, and not subjected to severe wet weather or long-continued drought, it may be a fairly good road In wet weather water can get in where it has come out, reproducing the mud soup, and the traffic squeezes it up and out of the road In dry weather the binding being reduced in bulk and loosened by the evaporation of the moisture, which gave the inserted dirt some cohesion, the stones move and are picked out of the surface, and so holes are left for the water to lodge in the dirt below when again rain begins to fall What would Macadam say if he could visit the scene of his scientific

labours, to hear the phrase 'water binding' used to describe the means employed for consolidating the crust. To call a water-formed road a 'macadamised' road is a contradiction in terms. His emphatic declaration was: 'Every road is to be made of broken stones, without mixture of earth, clay, chalk, or any other matter that will imbibe water.'

But further, another disadvantage has shown itself very markedly as a result of steam-rolling The heavy road-roller coming on to a layer of stones, surrounded with liquid—and therefore non-resisting—mud, and pressing down the stones by its weight, necessarily must move the water and the dirt in suspension, otherwise the stones would not go close together The liquid is therefore squeezed out of the way, and as the great width of the roller prevents its escape sideways, except at the edges, it must go forwards, and (water being practically incompressible) the water and the dirt and the stones in front are forced upwards, forming a ridge before the roller. (*Diagram shown*) It advances, and when it cannot force the ridge farther forward, it then mounts it and descends in front, and so *da capo*, with the consequence that the road becomes a series of ridges and furrows, and when drying up resembles a mackerel's side, a series of dark-toned wet hollows, and light-toned dry mounds The road becomes bumpy for the traveller, and is unable to free its surface from water, and the material remaining soft and wet in the furrows, and becoming dry in the ridges, is open to destruction by the feet of the horses and the wheels of vehicles dumping down and striking compressing blows in the hollows No worse state of matters for the traveller and his vehicle, or for durability of the road surface, can be conceived Yet any observant person must have seen this road condition extending for long distances within a very short time after the crust has been put down

Then let me call attention to another evil which is the consequence of rolling wet mud into the interstices of the road Whenever the slightest depression takes place, and water lodges in it, the horse's hoof or the wheel descending into the depression forces out the water and with it the dirt binding and throws it on to the surface of the road It is commonly supposed that the potholes which show themselves in roads over which heavy traffic passes are caused by an alleged sucking action of the pneumatic tires of the motor vehicle This is a mistake The proof that there is no appreciable sucking action is shown by the fact—which anyone can observe for himself—that where a wheel with studs has passed over a stretch of half-dried mud, the impressions of the studs are as sharp and as exact in roundness as when they were made by the stud descending on to the road. This would be impossible if the tire had a sucking action. The marks would then be ragged, and there would be loose mud lying on the line of the track. What actually happens, when the tire strikes a wet, muddy part of the road, and most of all when it strikes down with a blow into puddle depressions, is that the water below, being squeezed out sideways, carries with it the soft mud in the hole, which is shot out horizontally from the track I show you a diagram of the appearance of the road after the vehicle has dumped down into the depression There is the clean tire mark Outside it

there is a broken ridge of dirt on both sides, and out beyond these ridges are loose pieces of mud, thrown to some distance. I measured the discharge from a pothole, in a case where the mud had some consistency, and found that the pieces of mud thrown out reached more than six feet from the tire mark The case was one in which the speed of the vehicle was not more than 15 miles an hour. I also show you a diagram of a pothole It consists of a round group of stones, bare of all covering, and pushed down below the level of the road, and round it thick mud gradually thinning outwards. Every time a hoof or a wheel has to fall into it more dirt is thrown out In wet weather it fills with water, which works its way all around, and brings the crust of the road to destruction The increase of potholes is not caused by the change from horse to motor traffic It is caused by increased traffic on roads badly constructed If anyone desires to be assured that potholes are formed by horse traffic, let him examine the Trossachs road, a road on which no motor vehicle is permitted to run I went over a cross-road a few days ago, where not more than one motor-car passes in a month, and I found it full of potholes There will always be potholes in roads where a good deal of traffic passes, as long as road metal is mixed with mud and rolled down, as is at present the practice

Another evil which developed itself as a consequence of the adoption of steam-rolling has been the too common use of stones of larger size than those prescribed by Macadam His metal had to pass through a 1½-inch gauge At first, for the guidance of the labourer, who was not to be trusted for careful measurement, he gave as a formula that the stone-breaker should be able to insert any of his stones into his mouth But he had to give this up When he was inspecting road work near Bristol, he came upon a pile of stones which were of much larger size than his specification to the contractor required He at once found fault with the very tall stone-breaker, holding up to him a stone from the pile The man, being a Scotsman like himself, responded in the vernacular 'Weel, Mr Macadam, ye tell't iss to break doon till we cud pit the stone in our mooth Look here'—and he opened a vast jaw stretching from ear to ear, and, showing a cavern with no teeth, made the impugned stone disappear This drove Macadam back to scientific rule, prescribing 1½ inch and no stone to exceed six ounces in weight He relied on the close packing of the small stone to give a good resisting surface, and did so successfully But for a good many years his rule has been departed from. (*Specimens of Macadam stone and of stone used now shown*) Here is a stone which I picked out of a road, not a mile from this place I put it in the scale, and I now count macadam stones into the other scale, and you see it takes 21 macadam stones to balance the single stone, although it has lost some weight by being moved in the road, for as you see the edges are all completely rounded off Let me illustrate to you the evils of using large stones I have laid in this box some ordinary macadam. On the top are three stones, one of macadam size and two of greater size, which were taken from a road I have attached sticks with coloured discs to the stones. When I press on the macadam stone the disc does not rise, as the stone does not tilt, but when I press on the others

at the same distance in from the end of the stone as in the case of the macadam, the stone is immediately tilted up out of the road. The same thing happens when a heavy horse puts his shoe on the end of a stone, or the edge of an iron wheel presses it down The stone being freed from its socket, the road at that point is spoiled, presenting a hollow in which water can lodge, and the sides of which can be crushed down by the traffic, with fatal result to road efficiency. The effect is even worse if round stones with no sharp-edged surfaces are used (*Stones shown*) Such stones must work loose and leave a hole to be widened and deepened, and filled with water when rain falls

Another evil is that too often the camber of the road is made too high, it being the practice to pile stones on the centre of the way, without making such arrangements as will keep the curve of the road low The result is that drivers, to escape the extra strain on their horses by driving along the side of a slope, and to avoid slipping down to the gutter when the road is greasy, keep on the very centre of the road, on which two ruts are soon formed which gradually get deeper, and in which water lodges, with most disastrous effect, the water being splashed out by the wheel, and mud being forced up and out by the blow struck when the tire goes down into the hollows formed (*Two diagrams shown*)

Speaking of the blows struck leads me to say that the road made of stones with mud in between them is a road in which at every stroke of the horse, especially the heavy horse with a heavy iron shoe such as I show you (*large shoe with calkins shown*), shakes and moves the stones in the crust many inches below the surface The same occurs when there is any depression into which the wheel goes down with violence The consequence is that the crust becomes unstable, the stones below the surface being moved about and their sharp binding surfaces destroyed, by which the life of the crust is much diminished That the stones are moved I can demonstrate to you The Edinburgh Surveyor cut out for me a piece of mud-bound—or, as it is incorrectly called, water-bound—macadam, and these stones which I show you were taken out at a depth of six inches You will observe that all their angles are rounded off, so that they have become of an irregular egg-like shape They have been constantly moved, and they are therefore incapable of being bound to form a firm crust, without which no road can stand under traffic

Such was the state of matters when the power-vehicle was brought upon the road It soon became apparent that the traffic would be very greatly increased, that enormous numbers of passenger vehicles and of commercial vehicles were being used on the road, doing work which for half a century had been done by the railroads To-day it is impossible to dispute the fact that the mechanically-driven vehicle is predominant, that the use of horsed vehicles is steadily diminishing, and that on many roads where 20 to 50 vehicles passed in the day, 200 or 300 or even more traverse the highway I show you a diagram made from personal observation Counting the passing vehicles till the number of 500 motor vehicles was reached, it was found that only 10 horsed vehicles passed in the same time This was during last year. I was so astonished at the result that I took a check-count for a few minutes, and found that

47 motor vehicles went past before one horsed vehicle was seen In the present year the facts are still more extraordinary. An observation was taken in the evening at the top of the Haymarket in London, where five roads meet, and all the traffic has to pass through a crossing 46 feet wide In one hour there passed 2,499 vehicles. Of these the proportions were:—

Power vehicles	Horsed vehicles
2,445	54

A second check-test gave a practically similar result —

Power vehicles	Horsed vehicles
2,245	35

Such figures speak with irresistible eloquence There are very few people now who, like the courtiers of Canute, think that the tide can be kept back by word of command It is overwhelming, and every person not blinded by unreasoning prejudice must realise that the old idea which held that the traffic must be controlled by the road is gone for ever The traffic must rule the road Whatever is necessary to enable the traffic to be carried on with efficiency must be done Already vast numbers of passengers and vast quantities of goods are being carried by road, and the number is increasing and will increase in a degree of which few have real perception The mechanically-propelled vehicle has conquered the road for itself once and for all, and the road must be made to carry it efficiently, safely, and economically. And in so adapting the road to the traffic, the prospect before the community is that it will be a mudless, a dustless, and a smooth way, to a great improvement in personal comfort, a great saving of expense in power, and great economy in the maintenance of vehicles Further, the value to sound sanitation will be almost incalculable

What is the road of the future to be? It is a question which all who are associated with the management of roads have come to see calls imperatively for an answer The problem is to find the best mode by which a road can be constructed which will not have its surface broken by traffic, and will make transit easier both for passengers and goods, and shall neither form puddle holes nor exude mud to clog the vehicles and to form thick dust when the weather is dry, in short, that there shall be no loose material from the road, except the small quantity caused by surface wear, which it is found is but trifling when a sound crust has been rolled in. That such a road can be laid anyone may see by paying a visit to the Thames Embankment, the traffic on which was small formerly, the road being shunned as one of the worst in the country, but which is now used by an enormous number of vehicles, often as many as 1,600 in an hour. It will be seen there that water on the surface dries off very quickly, there being no mass of mud to hold it, and that in the driest weather there is practically no dust No watering is done during the day, the surface receiving one washing during the night because of the horse traffic. But there is no need for the use of water carts by day. Even during the long drought of 1911 there was no watering, yet there was no appreciable dust

His Majesty's Road Board has been appointed, and all the money

obtained from motor licences and from the petrol tax is put into our hands for the encouragement of road improvement, and the ascertainment by experiment of the best modes of effecting such improvement.

As regards grants, these are given when any approved improvement is executed, and may, according to circumstances, be a half or two-thirds or even more of the cost, to be paid on the work being done to our satisfaction Or where extensive works are taken in hand, money may be given in loan at low interest, or without interest, repayable over a course of years Roughly speaking, about a million pounds sterling per annum is available, which forms a most substantial help to road improvement And as the number of vehicles increases, which it is doing by many thousands a year, the product of the licences and the petrol tax will increase in proportion Of course things must move gradually In our first Board year, one single county in the north of Scotland put in a claim amounting to £750,000, being equal to the whole income then available for the three kingdoms. We cannot meet such claims.

As regards research, we are carrying on, under our able engineer Colonel Crompton, and our skilled Advisory Board, experiments both in the laboratory and on the road The laboratory experiments are directed to ascertain what are the best materials, to determine the proportions as regards size and quantity of the substances found to be suitable, to fix the proper thicknesses of road crusts according to the traffic they have to bear, and last, but not least, to endeavour to determine whether any, and if so what, protecting skin shall be placed on the surface so as to come between the hoof or wheel and the bearing crust to protect it from being attacked directly by the traffic

I shall conclude by calling your attention to some of the results of recent experiments, by which valuable and practical information has been obtained, ensuring that good roads can be made which will keep their surface sound for twice as long as the water-bound road, and will not become uneven and break into holes as did the roads of the past, which were rough, muddy, and dusty according to the weather, deteriorating in a marked manner within a short time after they had been laid down, and in times of heavy and continuous rain having their binding washed out or carried down to the gutters, or left lying thick at the bottom of the slope wherever there was a gradient of any steepness And let it be realised that in proportion to the degree in which improvement becomes attainable, not only will comfort and convenience be augmented, but the wear and tear of horses, of vehicles, and of tires will be lessened in a marked degree, and the moving of passengers and goods be facilitated more and more, leading to economy in transit

Considering what is to be the road of the future, the important question is 'What shall be the weight-bearing crust?' and this is engaging the attention of the advisers of the Road Board One thing is now universally recognised, that the road of the future shall be a truly bound road, in which, whatever kind of stone is used—a matter into which there is not time to enter—that stone shall be held together by some pitchy or bituminous material, so that it shall be indeed a crust and not something which has no real cohesion, and into which Macadam's enemy, the water, can make its way whenever water falls

That this result has been attained in a practical way is manifest from the pieces of road crust cut out after they have been under traffic for long periods, and which I now show you (*Specimens exhibited*.) You will see, if you care to examine them afterwards, that the stones are in their places as they were laid down with their plastic binding, that no water has penetrated and that no stones have been picked out or forced out by the traffic, and that the stones have been held so that they have kept their angularity, and therefore do not tend to come out of the road. Experience tends to show that such a road will remain sound, and that for even twice the period that is possible in the case of a mud-water bound road. That you may see how cohesive such a road is, Colonel Crompton has prepared for me these specimens of road, showing how they will hang as a solid piece even with a heavy weight attached, which of course would be impossible with water-bound material. It could not be held up at all, but would fall to pieces in the very act of taking it out of the road. (*Specimens shown*.)

Roads formed as regards the crust in this way are now common. There is reason for thinking, from experiments made, that possibly it is unnecessary, and indeed disadvantageous, to use any stones of size—even of Macadam's 1½-inch—in making the crust. Experiment is tending to show that suitable stone, reduced to very small size, such as I show you—(*specimen shown*)—and properly treated with a binder, will produce crust material of a most satisfactory kind. I have here numerous briquettes of such a combination of small stone bound with suitable material which have proved to be of great strength.

It will be observed, if the specimens are examined, that the cohesion is so close that when fracture occurs the stone, in many cases, is not pulled out of the structure, but is broken across, its halves remaining embedded in the binding material. These briquettes of six square inches of surface will resist a pressure applied to the unsupported middle of several hundred pounds, while ordinary crust material would break on a slight pressure. It is the difference between material that will crumble and material that will cling together—between stone set in mud and stone bound with a strongly cohering substance.

One question remains—will it not be well to endeavour to provide an elastic skin or carpet to lie between the vehicle and the bearing crust? This question is also engaging attention. Can we find some material for the exposed surface of the road which shall be resilient, yielding to traffic, but resuming its form and surface? Just as in a golf club house we protect our floor from being dug into and worn away by the hob-nailed shoes of the golfer by using a thin film of semi-resilient covering, such as kamptulicon or ribbed indiarubber, so it is a question whether we may not protect our road floor—the road crust—by covering it with a film of some substance which will yield and recover without disintegrating in the process. The laboratory experiments made seem to indicate that this will be accomplished. There are certain materials which at ordinary temperatures are, though solid to look at, really in a liquid though viscous state. They will flow, but slowly. Their surface if pressed down will yield, but in time will resume its level. It is of such viscous pitchy material that the stones of the crust are bound

together A material to be used for an elastic carpet for the road crust must have a more elastic quality, and for this a high class of bitumen, mixed with sand, is used (*Specimen of bitumen shown.*) You will observe that it is capable of being twisted without fracture and when freed slowly resumes its shape.

It is expected that with such material mixed with small stone and sand a valuable road protection will be supplied, so that the road crust will be practically permanent, the upper protecting sheet being re-made up and re-laid as required

Time will not permit that I should go into detail in this matter, and in any view it is still in degree in the experimental stage; but let me indicate how such a protective film will operate We know that if a wooden floor be left bare, persons going over it will cause much noise, and if instead boots be used this will affect the surface more rapidly than if felt shoes are worn As regards the noise, which is the thing most thought of, it is of course a fact that it is only an effect of the motion of the floor caused by shock as it is struck by the successive blows of the feet coming down upon it Let a person slide over it without raising the feet and there will be little or no noise But the blows of the feet make the whole floor shake, and the vibration causes the noise It is by preventing the vibration that we prevent the noise, so we put carpets or kamptulicon or oil-cloth over it The blows fall just the same, but the covering, yielding and absorbing the effect of the blow, prevents the floor from vibrating under shock, and so the annoyance of noise is cured. It is the same in the case of the road. The horse strikes a blow on the ground at every pace, especially a heavy horse with enormous shoes, of which I show you a specimen, and the vehicle going over the unevenness of the road also strikes blows at every turn of the wheels This operates downwards on the road and upwards on the passenger in the vehicle The road as we have it suffers from these blows from the stones being caused to move and to lose their sharpness and become loosened in their hold

But if we can clothe the road with a compressible and elastic skin, which will yield and recover, then the main crust may last efficiently for an indefinite period, and the road be less unkind than it often is to persons and vehicles.

For this carpet or topping, strength is not of so much importance as the elastic and silencing qualities, and the freedom from liability to produce any dust in summer or mud in winter.

Our engineers tell us that this ideal road of the future need not be a costly one, on the contrary, that once the matter is thoroughly understood, and the road-men trained to the new methods, the rapidly increasing traffic of the time before us will be carried with little or no increase in the cost of maintenance, and probably in some cases with a decrease.

I thank you for your patience, and ask to be allowed to express the hope and to make the request that you will take an interest in road improvement, which will not only add to your own comfort, but will tend to increase commercial prosperity, to give greater efficiency of land defence, and last, but not least, will be a powerful agent in improving

sanitary conditions, particularly in towns. May our future roads be in true contrast in efficiency, in durability, and in cleanliness to the roads of the past. Give your hearty encouragement to all who are endeavouring to make the road more smooth, more convenient, and more cleanly, and so more healthy. The raising of the quality of the road is a work which can do harm to no one, and must do good to all. I hope you will all in your respective circles do what you can to promote road improvement. By doing so you will add to the conveniences of life, and to your own comfort, and we of the Road Board will be grateful for your help.

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

Section A —MATHEMATICAL AND PHYSICAL SCIENCE

PRESIDENT OF THE SECTION —PROFESSOR H L CALLENDAR, LL D , F R S

THURSDAY, SEPTEMBER 5

The President delivered the following Address —

My first duty on taking the chair is to say a few words in commemoration of the distinguished members whom we have lost since the last meeting.

George Chrystal, Professor of Mathematics in the University of Edinburgh for more than thirty years, officiated as President of this Section in the year 1885, and took a prominent part in the advancement of science as Secretary of the Royal Society of Edinburgh since 1901 Of his brilliant mathematical work and his ability in developing the school at Edinburgh I am not competent to speak, but I well remember as a student his admirable article on 'Electricity and Magnetism' contributed to the 'Encyclopædia Britannica,' which formed at that time the groundwork of our studies at Cambridge under Sir J. J Thomson. It would be difficult to find a more complete and concise statement of the mathematical theory at the time when that article was written One can well understand the value of such a teacher, and sympathise with his University in the loss they have sustained

John Brown, F R S , who acted as Local Secretary for the Association at Belfast in 1902, will be remembered for his work on the Volta contact effect between metals, which he showed to be in the main dependent on chemical action, and to be profoundly affected by the nature of the gas or other medium in which the plates were immersed Although the theory of this difficult subject may not yet be completely elucidated, there can be little doubt that his work takes the first rank on the experimental side

William Sutherland, D Sc , who at one time acted as Professor of Physics at Melbourne, is best known for his familiar papers on the subject of molecular physics in the 'Philosophical Magazine' His work was always remarkable for its wide range and boldness of imagination Many of his hypotheses cannot yet be weighed in the balance of experiment, but some have already been substantiated For instance, his theory of the variation of viscosity of gases with temperature has been generally accepted, and results are now commonly expressed in terms of Sutherland's constant

Osborne Reynolds, the first Professor of Engineering at Owens College, was President of Section G in 1887, but belongs almost as much to mathematics and physics, in which his achievements are equally memorable It would be hardly possible for me to enumerate his important contributions to the science of engineering, which will be more fittingly commemorated elsewhere His mastery of mathematical and physical methods, while contributing greatly to his success as a pioneer in the engineering laboratory, enabled him to attack the most difficult problems in physics, such as the theory of the radiometer and the thermal transpiration of gases. His determination of the mechanical equivalent of heat

is a most striking example of accurate physical measurement carried out on an engineering scale His last great work, on the 'Submechanics of the Universe,' is so original in its ideas and methods that its value cannot yet be fully appreciated While it differs so radically from our preconceived ideas that it fails to carry immediate conviction, it undoubtedly represents possibilities of truth which subsequent workers in the same field cannot afford to ignore.

The present year has been one of remarkable activity in the world of Mathematical and Physical Science, if we may measure activity by the number and importance of scientific gatherings like the present for the interchange of ideas and the general advancement of science The celebration of the 250th Anniversary of the Foundation of the Royal Society brought to our shores a number of distinguished delegates from all parts of the world, to promote the ever-growing fellowship among men of science which is one of the surest guarantees of international progress The Congress of Universities of the Empire brought other guests from distant British dominions, and considered, as one of the principal points in its programme, the provision of facilities for the interchange of students between different universities, which will doubtless prove particularly advantageous to the scientific student in the higher branches of research In the special branches of knowledge more particularly associated with this Section, the International Congress of Mathematics at Cambridge, while it affords to Cambridge men like myself a most gratifying recognition of our *Alma Mater* as one of the leading schools of mathematics in the world, has given us the opportunity of meeting here a number of distinguished foreign mathematicians, whose presence and personality cannot be otherwise than inspiring to our proceedings, and will compensate for any deficiency in our own mathematical programme The Optical Convention held this year in London, by the importance of the papers contributed for discussion, and by its admirable exhibition of British instruments, has revealed the extent of our optical industry and talent, and has done much to dispel the impression, fostered by an unfortunate trade regulation, that the majority of optical instruments were 'made elsewhere' The Radio-Telegraphic Conference, held under the auspices of the British Government, has formulated recommendations for regulating and extending the application of the discoveries of modern physics for saving life and property at sea The work of this Conference will be fittingly supplemented on the scientific side by the discussion on wireless telegraphy which has been arranged to take place in this Section in conjunction with Section G

It would be impossible, even if it were not out of place, for me to attempt to review in detail the important work of these congresses, a full account of which will shortly be available in their several reports of proceedings now in course of publication In the present age of specialisation and rapid publication it would be equally impossible to give any connected account in the time at my disposal of recent developments in those branches of science which come within the range of our Section The appropriate alternative adopted by the majority of my predecessors in this chair, is to select some theory or idea sufficiently fundamental to be of general interest, and to discuss it in the light of recent experimental evidence It may sometimes be advantageous to take stock of our fundamental notions in this way, and to endeavour to determine how far they rest on direct experiment, and how far they are merely developments of some dynamical analogy, which may represent the results of experiment up to a certain point, but may lead to erroneous conclusions if pushed too far With this object I propose to consider on the present occasion some of our fundamental ideas with regard to the nature of heat, and in particular to suggest that we might with advantage import into our modern theory some of the ideas of the old caloric or material theory which has for so long a time been forgotten and discredited. In so doing I may appear to many of you to be taking a retrograde step, because the caloric theory is generally represented as being fundamentally opposed to the kinetic theory and to the law of the conservation of energy I would, therefore, remark at the outset that this is not necessarily the case, provided that the theory is rightly interpreted and applied in accordance with experiment Mistakes have been made on both theories, but the method commonly adopted of selecting all the mistakes made in the application of the caloric theory and contrasting them with the correct deductions from the kinetic theory has created an erroneous

impression that there is something fundamentally wrong about the caloric theory, and that it is in the nature of things incapable of correctly representing the facts I shall endeavour to show that this fictitious antagonism between the two theories is without real foundation They should rather be regarded as different ways of describing the same phenomena Neither is complete without the other The kinetic theory is generally preferable for elementary exposition, and has come to be almost exclusively adopted for this purpose, but in many cases the caloric theory would have the advantage of emphasising at the outset the importance of fundamental facts which are too often obscured in the prevailing method of treatment.

The explanation of the development of heat by friction was one of the earliest difficulties encountered by the caloric theory One explanation, maintained by Cavendish and others, was simply that caloric was generated *de novo* by friction in much the same way as electricity Another explanation, more commonly adopted, was that the fragments of solid, abraded in such operations as boring cannon, had a smaller capacity for heat than the original material Caloric already existing in the substance was regarded as being squeezed or ground out of it without any fresh caloric being actually generated The probability of the second explanation was negatived by the celebrated experiments of Rumford and Davy, who concluded that friction did not diminish the capacities of bodies for heat, and that it could not be a material substance because the supply obtainable by friction appeared to be inexhaustible Rumford also showed that no increase of weight in a body when heated could be detected by the most delicate apparatus available in his time Caloric evidently did not possess to any marked extent the properties of an ordinary ponderable fluid, but, if it had any real existence and was not merely a convenient mathematical fiction, it must be something of the same nature as the electric fluids, which had already played so useful a part in the description of phenomena, although their actual existence as physical entities had not then been demonstrated. Heat, as Rumford and Davy maintained, might be merely a mode of motion or a vibration of the ultimate particles of matter, but the idea in this form was too vague to serve as a basis of measurement or calculation The simple conception of caloric, as a measurable quantity of something, sufficed for many purposes, and led in the hands of Laplace and others to correct results for the ratio of the specific heats, the adiabatic equation of gases, and other fundamental points of theory, though many problems in the relations of heat and work remained obscure

The greatest contribution of the caloric theory to thermodynamics was the production of Carnot's immortal 'Reflections on the Motive Power of Heat' It is one of the most remarkable illustrations of the undeserved discredit into which the caloric theory has fallen, that this work, the very foundation of modern thermodynamics, should still be misrepresented, and its logic assailed, on the ground that much of the reasoning is expressed in the language of the caloric theory In justice to Carnot, even at the risk of wearying you with an oft-told tale, I cannot refrain from taking this opportunity of reviewing the essential points of his reasoning, because it affords incidentally the best introduction to the conception of caloric, and explains how a quantity of caloric is to be measured

At the time when Carnot wrote, the industrial importance of the steam-engine was already established, and the economy gained by expansive working was generally appreciated The air-engine, and a primitive form of the internal-combustion engine, had recently been invented On account of the high value of the latent heat of steam, it was confidently expected that more work might be obtained from a given quantity of heat or fuel by employing some other working substance, such as alcohol or ether, in place of steam Carnot set himself to investigate the conditions under which motive-power was obtainable from heat, how the efficiency was limited, and whether other agents were preferable to steam These were questions of immediate practical importance to the engineer, but the answer which Carnot found embraces the whole range of science in its ever-widening scope

In discussing the production of work from heat it is necessary, as Carnot points out, to consider a complete series or cycle of operations in which the working substance, and all parts of the engine, are restored on completion of the

cycle, to their initial state Nothing but heat, or its equivalent fuel, may be supplied to the engine Otherwise part of the motive power obtained might be due, not to heat alone, but to some change in the working substance, or in the disposition of the mechanism. Carnot here assumes the fundamental axiom of the cycle, which he states as follows . '*When a body has undergone any changes, and, after a certain number of transformations, is brought back identically to its original state, considered relatively to density, temperature, and mode of aggregation, it must contain the same quantity of heat as it contained originally*' This does not limit the practical application of the theory, because all machines repeat a regular series of operations, which may be reduced in theory to an equivalent cycle in which everything is restored to its initial state

The most essential feature of the working of all heat-engines, considered apart from details of mechanism, is the production of motive-power by alternate expansion or contraction, or heating and cooling of the working substance This necessitates the existence of a difference of temperature, produced by combustion or otherwise, between two bodies, such as the boiler and condenser of a steam-engine, which may be regarded as the source and sink of heat respectively Wherever a difference of temperature exists, it may be made a source of motive-power, and conversely, without difference of temperature, no motive-power can be obtained from heat by a cyclical or continuous process From this consideration Carnot deduces the simple and sufficient rule for obtaining the maximum effect '*In order to realise the maximum effect it is necessary that, in the process employed, there should not be any direct interchange of heat between bodies at sensibly different temperatures*' Direct transference of heat between bodies at sensibly different temperatures would be equivalent to wasting a difference of temperature which might have been utilised for the production of motive-power Equality of temperature is here assumed as the limiting condition of thermal equilibrium, such that an infinitesimal difference of temperature will suffice to determine the flow of heat in either direction An engine satisfying Carnot's rule will be reversible so far as the thermal operations are concerned Carnot makes use of this property of reversibility in deducing his formal proof that an engine of this type possesses the maximum efficiency If in the usual or direct method of working such an engine takes a quantity of heat Q from the source, rejects heat to the condenser, and gives a balance of useful work W per cycle, when the engine is reversed and supplied with motive-power W per cycle it will in the limit take the same quantity of heat from the condenser as it previously rejected, and return to the source the same quantity of heat Q as it took from it when working direct All such engines must have the same efficiency (measured by the ratio W/Q of the work done to the heat taken from the source) whatever the working substance, provided that they work between the same temperature limits For, if this were not the case, it would be theoretically possible, by employing the most efficient to drive the least efficient reversible engine backwards, to restore to the source all the heat taken from it, and to obtain a balance of useful work without the consumption of fuel, a result sufficiently improbable to serve as the basis of a formal proof Carnot thus deduces his famous principle, which he states as follows '*The motive-power obtainable from heat is independent of the agents set at work to realise it Its quantity is fixed solely by the temperatures between which in the limit the transfer of heat takes place*'

Objection is commonly taken to Carnot's proof, on the ground that the combination which he imagines might produce a balance of useful work without infringing the principle of conservation of energy, or constituting what we now understand as perpetual motion of the ordinary kind in mechanics It has become the fashion to introduce the conservation of energy in the course of the proof, and to make a final appeal to some additional axiom. Any proof of this kind must always be to some extent a matter of taste; but since Carnot's principle cannot be deduced from the conservation of energy alone, it seems a pity to complicate the proof by appealing to it For the particular object in view, the absurdity of a heat-engine working without fuel appears to afford the most appropriate improbability which could be invoked The final appeal must be to experiment in any case. At the present time the experimental verification of Carnot's principle in its widest application so far outweighs the validity of any deductive proof, that we might well rest content with the logic that satisfied Carnot instead of confusing the issue by disputing his reasoning.

Carnot himself proceeded to test his principle in every possible way by comparison with experiment so far as the scanty data available in his time would permit. He also made several important deductions from it, which were contrary to received opinion at the time. but have since been accurately verified He appears to have worked out these results analytically in the first instance, as indicated by his footnotes, and to have translated his equations into words in the text for the benefit of his non-mathematical readers In consequence of this, some of his most important conclusions appear to have been overlooked or attributed to others Owing to want of exact knowledge of the properties of substances over extended ranges of temperature, he was unable to apply his principle directly in the general form for any temperature limits We still labour to a less extent under the same disability at the present day. He showed, however, that a great simplification was effected in its application by considering a cycle of infinitesimal range at any temperature t In this simple case the principle is equivalent to the assertion that the work obtainable from a unit of heat per degree fall (or per degree range of the cycle) at a temperature t, is some function $F't$ of the temperature (generally known as Carnot's Function), which must be the same for all substances at the same temperature From the rough data then available for the properties of steam, alcohol, and air, he was able to calculate the numerical values of this function in kilogrammetres of work per kilocalorie of heat at various temperatures between 0° and 100° C , and to show that it was probably the same for different substances at the same temperature within the limits of experimental error For the vapour of alcohol at its boiling-point, 78°·7 C , he found the value $F't=1\ 230$ kilogrammetre per kilocalorie per degree fall For steam at the same temperature he found nearly the same value, namely, $F't = 1\ 212$ Thus no advantage in point of efficiency could be gained by employing the vapour of alcohol in place of steam He was also able to show that the work obtainable from a kilocalorie per degree fall probably diminished with rise of temperature, but his data were not sufficiently exact to indicate the law of the variation

The equation which Carnot employed in deducing the numerical values of his function from the experimental data for steam and alcohol is simply the direct expression of his principle as applied to a saturated vapour It is now generally known as Clapeyron's equation, because Carnot did not happen to give the equation itself in algebraic form, although the principle and details of the calculation were most minutely and accurately described In calculating the value of his function for air, Carnot made use of the known value of the difference of the specific heats at constant pressure and volume He showed that this difference must be the same for equal volumes of all gases measured under the same temperature and pressure, whereas it had always previously been assumed that the ratio (not the difference) of the specific heats was the same for different gases He also gave a general expression for the heat absorbed by a gas in expanding at constant temperature, and showed that it must bear a constant ratio to the work of expansion These results were verified experimentally some years later, in part by Dulong, and more completely by Joule, but Carnot's theoretical prediction has generally been overlooked, although it was of the greatest interest and importance The reason of this neglect is probably to be found in the fact that Carnot's expressions contained the unknown function $F't$ of the temperature, the form of which could not be deduced without making some assumptions with regard to the nature of heat and the scale on which temperature should be measured

It was my privilege to discover a few years ago that Carnot himself had actually given the correct solution of this fundamental problem in one of his most important footnotes, where it had lain buried and unnoticed for more than eighty years He showed by a most direct application of the caloric theory, that if temperature was measured on the scale of a perfect gas (which is now universally adopted) the value of his function $F't$ on the caloric theory would be the same at all temperatures, and might be represented simply by a numerical constant A (our 'mechanical equivalent') depending on the units adopted for work and heat In other words, the work W done by a quantity of caloric Q in a Carnot cycle of range T to T_0 on the gas scale would be represented by the simple equation :

$$W = AQ\,(T - T_0)$$

It is at once obvious that this solution, obtained by Carnot from the caloric

theory, so far from being inconsistent with the mechanical theory of heat, is a direct statement of the law of conservation of energy as applied to the Carnot cycle If the lower limit T_0 of the cycle is taken at the absolute zero of the gas-thermometer, we observe that the maximum quantity of work obtainable from a quantity of caloric Q at a temperature T is simply AQT, which represents the absolute value of the energy carried by the caloric taken from the source at the temperature T The energy of the caloric rejected at the temperature T_0 is AQT_0 The external work done is equal to the difference between the quantities of heat energy supplied and rejected in the cycle

The analogy which Carnot himself employed in the interpretation of this equation was the oft-quoted analogy of the waterfall Caloric might be regarded as possessing motive-power or energy in virtue of elevation of temperature just as water may be said to possess motive-power in virtue of its head or pressure The limit of motive-power obtainable by a reversible motor in either case would be directly proportional to the head or fall measured on a suitable scale Caloric itself was not motive-power, but must be regarded simply as the vehicle or carrier of energy, the production of motive-power from caloric depending essentially (as Carnot puts it) not on the actual consumption of caloric, but on the fall of temperature available The measure of a quantity of caloric is the work done per degree fall, which corresponds with the measure of a quantity of water by weight, *i e*, in kilogrammetres per metre fall

That Carnot did not pursue the analogy further, and deduce the whole mechanical theory of heat from the caloric theory, is hardly to be wondered at if we remember that no applications of the energy principle had then been made in any department of physics He appears, indeed, at a later date to have caught a glimpse of the general principle when he states that 'motive-power [his equivalent for work or energy] changes its form but is never annihilated ' It is clear from the posthumous notes of his projected experimental work that he realised how much remained to be done on the experimental side, especially in relation to the generation of caloric by friction, and the waste of motive-power by conduction of heat, which appeared to him (in 1824) 'almost inexplicable in the present state of the theory of heat '

One of the points which troubled him most in the application of the theoretical result that the work obtainable from a quantity of caloric was simply proportional to the fall of temperature available, was that it required that the specific heat of a perfect gas should be independent of the pressure This was inconsistent with the general opinion prevalent at the time, and with one solitary experiment by Delaroche and Bérard, which appeared to show that the specific heat of a gas diminished with increase of pressure, and which had been explained by Laplace as a natural consequence of the caloric theory Carnot showed that this result did not necessarily follow from the caloric theory, but the point was not finally decided in his favour until the experiments of Regnault, first published in 1852, established the correct values of the specific heat of gases, and proved that they were practically independent of the pressure

Another point which troubled Carnot was that, according to his calculations, the motive-power obtainable from a kilocalorie of heat per degree fall appeared to diminish with rise of temperature, instead of remaining constant This might have been due to experimental errors, since the data were most uncertain But if he had lived to carry out his projected experiments on the quantity of motive-power required to produce one unit of heat, and had obtained the result, 424 kilogrammetres per kilocalorie, subsequently found by Joule, he could hardly have failed to notice that this was the same (within the limits of experimental error) as the maximum work AQT obtainable from the kilocalorie according to his equation. (This is seen to be the case when the values calculated by Carnot per degree fall at different temperatures were multiplied by the absolute temperature in each case *E g*, 1 212 kilogrammetre per degree fall with steam at 79° C or 352° Abs $1{\cdot}212 \times 352 = 426$ kilogrammetres) The origin of the apparent discrepancy between theory and experiment lay in the tacit assumption that the quantity of caloric in a kilocalorie was the same at different temperatures There were no experiments at that time available to demonstrate that the caloric measure of heat as work per degree fall, implied in Carnot's principle, or more explicitly stated in his equation, was not the same as the calorimetric measure obtained by mixing substances at different temperatures. Even when the energy

principle was established its exponents failed to perceive exactly where the discrepancy between the two theories lay In reality both were correct, if fairly interpreted in accordance with experiment, but they depended on different methods of measuring a quantity of heat, which, so far from being inconsistent, were mutually complementary

The same misconception, in a more subtle and insidious form, is still prevalent in such common phrases as the following 'We now know that heat is a form of energy and not a material fluid' The experimental fact underlying this statement is that our ordinary methods of measuring quantities of heat in reality measure quantities of thermal energy When two substances at different temperatures are mixed, the quantity remaining constant, provided that due allowance is made for external work done and for external loss of heat, is the total quantity of energy. Heat is a form of energy merely because the thing we measure and call heat is really a quantity of energy Apart from considerations of practical convenience, we might equally well have agreed to measure a quantity of heat, in accordance with Carnot's principle, by the external work done in a cycle per degree fall Heat would then not be a form of energy, but would possess all the properties postulated for caloric The caloric measure of heat follows directly from Carnot's principle, just as the energy measure follows from the law of conservation of energy But the term *heat* has become so closely associated with the energy measure that it is necessary to employ a different term, *caloric*, to denote the simple measure of a quantity of heat as opposed to a quantity of heat energy The measurement of heat as caloric is precisely analogous to the measure of electricity as a quantity of electric fluid In the case of electricity, the quantity measure is more familiar than the energy measure, because it is generally simpler to measure electricity by its chemical and magnetic effects as a quantity of fluid than as a quantity of energy The units for which we pay by electric meter, however, are units of energy, because the energy supplied is the chief factor in determining the cost of production, although the actual quantity of fluid supplied has a good deal to do with the cost of distribution Both methods of measurement are just as important in the theory of heat, and it seems a great pity that the natural measure of heat quantity is obscured in the elementary stages of exposition by regarding heat simply as so much energy. The inadequacy of such treatment makes itself severely felt in the later stages

Since Carnot's principle was adopted without material modification into the mechanical theory of heat, it was inevitable that Carnot's caloric, and his solution for the work done in a finite cycle, should sooner or later be rediscovered Caloric reappeared first as the 'thermo-dynamic function' of Rankine, and as the 'equivalence-value of a transformation' in the equations of Clausius, but it was regarded rather as the quotient of heat energy by temperature than as possessing any special physical significance At a later date, when its importance was more fully recognised, Clausius gave it the name of *entropy*, and established the important property that its total quantity remained constant in reversible heat exchanges, but always increased in an irreversible process Any process involving a decrease in the total quantity of entropy was impossible Equivalent propositions with regard to the possibility or impossibility of transformations had previously been stated by Lord Kelvin in terms of the dissipation of available energy But, since Carnot's solution had been overlooked, no one at the time seems to have realised that entropy was simply Carnot's caloric under another name, that heat could be measured otherwise than as energy, and that the increase of entropy in any irreversible process was the most appropriate measure of the quantity of heat generated Energy so far as we know must always be associated with something of a material nature acting as carrier, and there is no reason to believe that heat energy is an exception to this rule The tendency of the kinetic theory has always been to regard entropy as a purely abstract mathematical function, relating to the distribution of the energy, but having no physical existence Thus it is not a quantity of anything in the kinetic theory of gases, but merely the logarithm of the probability of an arrangement In a similar way, some twenty years ago the view was commonly held that electric phenomena were due merely to strains in the ether, and that the electric fluids had no existence except as a convenient means of mathematical expression Recent discoveries have enabled us to form a more concrete conception of a charge of electricity, which has proved invaluable as a guide to research Perhaps

it is not too much to hope that it may be possible to attach a similar conception with advantage to caloric as the measure of a quantity of heat

It has generally been admitted in recent years that some independent measure of heat quantity as opposed to heat energy is required, but opinions have differed widely with regard to the adoption of entropy as the quantity factor of heat Many of these objections have been felt rather than explicitly stated, and are therefore the more difficult to answer satisfactorily Others arise from the difficulty of attaching any concrete conception of a quantity of something to such a vague and shadowy mathematical function as entropy The answer to the question, 'What is caloric?' must necessarily be of a somewhat speculative nature But it is so necessary for the experimentalist to reason by analogy from the seen to the unseen, that almost any answer, however crude, is better than none at all The difficulties experienced in regarding entropy as a measure of heat quantity are more of an academic nature, but may be usefully considered as a preliminary in attempting to answer the more fundamental question

The first difficulty felt by the student in regarding caloric as the measure of heat quantity is that when two portions of the same substance, such as water, at different temperatures are mixed, the quantity of caloric in the mixture is greater than the sum of the quantities in the separate portions The same difficulty was encountered by Carnot from the opposite point of view The two portions at different temperatures represented a possible source of motive-power The question which he asked himself may be put as follows · 'If the total quantity of caloric remained the same when the two portions at different temperatures were simply mixed, what had become of the motive-power wasted?' The answer is that caloric is generated, and that the quantity generated is such that its energy is the precise equivalent of the motive-power which might have been obtained if the transfer of heat had been effected by means of a perfect engine working without generation of caloric The caloric generated in wasting a difference of temperature is the necessary and appropriate measure of the quantity of heat obtained by the degradation of available motive-power into the less available or transformable variety of heat energy

The processes by which caloric is generated in mixing substances at different temperatures, or in other cases where available motive-power is allowed to run to waste, are generally of so turbulent a character that the steps of the process cannot be followed, although the final result can be predicted under given conditions from the energy principle Such processes could not be expected *à priori* to throw much light on the nature of caloric The familiar process of conduction of heat through a body, the parts of which are at different temperatures, while equally leading to the generation of a quantity of caloric equivalent to the motive-power wasted, affords better promise of elucidating the nature of caloric, owing to the comparative simplicity and regularity of the phenomena, which permit closer experimental study The earliest measurements of the relative conducting powers of the metals for heat and electricity showed that the ratio of the thermal to the electric conductivity was nearly the same for all the pure metals, and suggested that, in this case, the carriers of heat and electricity were the same Later and more accurate experiments showed that the ratio of the conductivities was not constant, but varied nearly as the absolute temperature. At first sight this might appear to suggest a radical difference between the two conductivities, but it results merely from the fact that heat is measured as energy in the definition of thermal conductivity, whereas electricity is measured as a quantity of fluid If thermal conductivity were defined in terms of caloric or thermal fluid, the ratio of the two conductivities would be constant with respect to temperature almost, if not quite, within the limits of error of experiment On the hypothesis that the carriers are the same for electricity and heat, and that the kinetic energy of each carrier is the same as that of a gas molecule at the same temperature, it becomes possible, on the analogy of the kinetic theory of gases, to calculate the actual value of the ratio of the conductivities The value thus found agrees closely in magnitude with that given by experiment, and may be regarded as confirming the view that the carriers are the same, although the hypotheses and analogies invoked are somewhat speculative

When the electrons or corpuscles of negative electricity were discovered it was a natural step to identify them with the carriers of energy, and to imagine that a metal contained a large number of such corpuscles, moving in all directions,

and colliding with each other, and with the metallic atoms, like the molecules of a gas on the kinetic theory. If the mass of each carrier were 1/1700 of that of an atom of hydrogen, the velocity at 0° C. would be about sixty miles a second, and would be of the right order of magnitude to account for the observed values of the conductivities of good conductors, on the assumption that the number of negative corpuscles was the same as the number of positive metallic atoms, and that the mean free path of each corpuscle was of the same order as the distance between the atoms The same hypothesis served to give a qualitative account of thermo-electric phenomena, such as the Peltier and Thomson effects, and of radiation and absorption of heat, though in a less satisfactory manner. When extended to give a consistent account of *all* the related phenomena, it would appear that the number of free corpuscles required is too large to be reconciled, for instance, with the observed values of the specific heat, on the assumption that each corpuscle possesses energy of translation equal to that of a gas molecule at the same temperature

Sir J J Thomson has accordingly proposed and discussed another possible theory of metallic conduction, in which the neutral electric doublets present in the metal are supposed to be continually interchanging corpuscles at a very high rate Under ordinary conditions these interchanges take place indifferently in all directions, but under the action of an electric field the axes of the doublets are supposed to become more or less oriented, as in the Grotthus-chain hypothesis of electrolytic conduction, producing a general drift or current proportional to the field. This hypothesis, though fundamentally different from the preceding or more generally accepted view, appears to lead to practically the same relations, and is in some ways preferable, as suggesting possible explanations of difficulties encountered by the first theory in postulating so large a number of free negative corpuscles On the other hand, the second theory requires that each neutral doublet should be continually ejecting corpuscles at the rate of about 10^{15} per second There are probably elements of truth in both theories, but, without insisting too much on the exact details of the process, we may at least assert with some confidence that the corpuscles of caloric which constitute a current of heat in a metal are very closely related to the corpuscles of electricity, and have an equal right to be regarded as constituting a material fluid possessing an objective physical existence

If I may be allowed to speculate a little on my own account (as we are all here together in holiday mood, and you will not take anything I may say too seriously), I should prefer to regard the molecules of caloric, not as being identical with the corpuscles of negative electricity, but as being neutral doublets formed by the union of a positive and negative corpuscle, in much the same way as a molecule of hydrogen is formed by the union of two atoms Nothing smaller than a hydrogen atom has yet, so far as I know, been discovered with a positive charge This may be merely a consequence of the limitations of our experimental methods, which compel us to employ metals to so large an extent as electrodes In the symmetry of nature it is almost inconceivable that the positive corpuscle should not exist, if only as the other end of the Faraday-tube or vortex-filament representing a chemical bond Professor Bragg has identified the X or γ rays with neutral corpuscles travelling at a high velocity, and has maintained this hypothesis with brilliant success against the older view that these rays are not separate entities, but merely thin, spreading pulses in the æther produced by the collisions of corpuscles with matter I must leave him to summarise the evidence, but if neutral corpuscles exist, or can be generated in any way, it should certainly be much easier to detach a neutral corpuscle from a material atom or molecule than to detach a corpuscle with a negative charge from the positive atom with which it is associated We should therefore expect neutral corpuscles to be of such exceedingly common and universal occurrence that their very existence might be overlooked, unless they happened to be travelling at such exceptionally high velocities as are associated with the γ rays According to the pulse theory, it is assumed that all γ rays travel with the velocity of light, and that the enormous variations observed in their penetrative power depend simply on the thickness of the pulse transmitted On the corpuscular theory, the penetrative power, like that of the α and β rays, is a question of size, velocity, and electric charge Particles carrying electric charges, like the α and β rays, lose energy in producing ions by their electric field, perhaps without actual collision Neutral or γ rays do

not produce ions directly, but dislodge either γ rays or β rays from atoms by direct collisions, which are comparatively rare The β rays alone, as C T. R Wilson's photographs show, are responsible for the ionisation. Personally, I have long been a convert to Professor Bragg's views on the nature of X rays, but even if we regard the existence of neutral corpuscles as not yet definitely proved, it is, I think, permissible to assume their existence for purposes of argument, in order to see whether the conception may not be useful in the interpretation of physical phenomena.

If, for instance, we assume that these neutral corpuscles or molecules of caloric exist in conductors and metallic bodies in a comparatively free state of solution, and are readily dissociated into positive and negative electrons owing to the high specific inductive capacity of the medium, the whole theory of metallic conduction follows directly on the analogy of conduction in electrolytic solutions But, whereas in electrolytes the ions are material atoms moving through a viscous medium with comparatively low velocities, the ions in metallic conductors are electric corpuscles moving with high velocities more after the manner postulated in the kinetic theory of gases It is easy to see that this theory will give similar numerical results to the electronic theory when similar assumptions are made in the course of the work But it has the advantage of greater latitude in explaining the vagaries of sign of the Hall effect, and many other peculiarities in the variation of resistance and thermo-electric power with temperature For good conductors, like the pure metals, we may suppose, on the electrolytic analogy, that the dissociation is practically complete, so that the ratio of the conductivities will approach the value calculated on the assumption that all the carriers of heat are also carriers of electricity But in bad conductors the dissociation will be far from complete, and it is possible to see why, for instance, the electric resistance of cast iron should be nearly ten times that of pure iron, although there is comparatively little difference in their thermal conductivities. The numerical magnitude of the thermo-electric effect, which is commonly quoted in explanation of the deviation of alloys from the electronic theory, is far too small to produce the required result, and there is little or no correspondence between the thermo-electric properties of the constituents of alloys and the variations of their electric conductivities

One of the oldest difficulties of the material theory of heat is to explain the process of the production of heat by friction The application of the general principle of the conservation of energy leads to the undoubted conclusion that the thermal energy generated is the equivalent of the mechanical work spent in friction, but throws little or no light on the steps of the process, and gives no information with regard to the actual nature of the energy produced in the form of heat It follows from the energy principle that the quantity of caloric generated in the process is such that its total energy at the final temperature is equal to the work spent If a quantity of caloric represents so many neutral molecules of electricity, one cannot help asking where they came from, and how they were produced It is certain that in most cases of friction, wherever slip occurs, some molecules are torn apart, and the work spent is represented in the first instance by the separation of electric ions Some of these ions are permanently separated as frictional electricity, and can be made to perform useful work, but the majority recombine before they can be effectively separated, leaving only their equivalent in thermal energy The recombination of two ions is generally regarded simply as reconstituting the original molecule at a high temperature, but in the light of recent discoveries we may perhaps go a step further. It is generally admitted that X or γ rays are produced by the sudden stoppage of a charged corpuscle, and Lorentz, in his electron theory of radiation, has assumed that such is the case however low the velocity of the electron A similar effect must occur in the sudden stoppage of a pair of ions rushing together under the influence of their mutual attraction Rays produced in this way would be of an exceedingly soft or absorbable character, but they would not differ in kind from those produced by electrons, except that their energy, not exceeding that of a pair of ions, would be too small to produce ionisation, so that they could not be detected in the usual way If the X rays are corpuscular in their nature, we cannot logically deny the corpuscular character even to the slowest moving rays We know that X rays continually produce other X rays of lower velocity The final stage is probably reached when the average

energy of an X corpuscle or molecule of caloric is the same as that of a gas molecule at the same temperature, and the number of molecules of caloric generated is such that their total energy is equal to the work originally spent in friction

In this connection it is interesting to note that Sir J J Thomson, in a recent paper on 'Ionisation by Moving Particles,' has arrived, on other grounds, at the conclusion that the character of the radiation emitted during the recombination of the ions will be a series of pulses, each pulse containing the same amount of energy and being of the same type as very soft X rays If the X rays are really corpuscular, these definite units or quanta of energy generated by the recombination of the ions bear a close resemblance to the hypothetical molecules of caloric

It may be objected that in many cases of friction, such as internal or viscous friction in a fluid, no electrification or ionisation is observable, and that the generation of caloric cannot in this case be attributed to the recombination of ions It must, however, be remarked that the generation of a molecule of caloric requires less energy than the separation of two ions, that, just as the separation of two ions corresponds with the breaking of a chemical bond, so the generation of one or more molecules of caloric may correspond with the rupture of a physical bond, such as the separation of a molecule of vapour from a liquid or solid The assumption of a molecular constitution for caloric follows almost of necessity from the molecular theories of matter and electricity, and is not inconsistent with any well-established experimental facts On the contrary, the many relations which are known to exist between the specific heats of similar substances, and also between the latent heats, would appear to lead naturally to a molecular theory of caloric For instance, it has often been noticed that the molecular latent heats of vaporisation of similar compounds at their boiling-points are proportional to the absolute temperature It follows that the molecular latent caloric of vaporisation is the *same* for all such compounds, or that they require the same number of molecules of caloric to effect the same change of state, irrespective of the absolute temperatures of their boiling-points From this point of view one may naturally regard the liquid and gaseous states as conjugate solutions of caloric in matter and matter in caloric respectively The proportion of caloric to matter varies regularly with pressure and temperature, and there is a definite saturation limit of solubility at each temperature

One of the most difficult cases of the generation of caloric to follow in detail is that which occurs whenever there is exchange of heat by radiation between bodies at different temperatures If radiation is an electro-magnetic wave-motion, we must suppose that there is some kind of electric oscillator or resonator in the constitution of a material molecule which is capable of responding to the electric oscillations If the natural periods of the resonators correspond sufficiently closely with those of the incident radiation the amplitude of the vibration excited may be sufficient to cause the ejection of a corpuscle of caloric It is generally admitted that the ejection of an electron may be brought about in this manner, but it would evidently require far less energy to produce the emission of a neutral corpuscle, which ought therefore to be a much more common effect On this view, the conversion of energy of radiation into energy of caloric is a discontinuous process taking place by definite molecular increments, but the absorption or emission of radiation itself is a continuous process Professor Planck, by a most ingenious argument based on the probability of the distribution of energy among a large number of similar electric oscillators (in which the entropy is taken as the logarithm of the probability, and the temperature as the rate of increase of energy per unit of entropy), has succeeded in deducing his well-known formula for the distribution of energy in full radiation at any temperature; and has recently, by a further extension of the same line of argument, arrived at the remarkable conclusion that, while the absorption of radiation is continuous, the emission of radiation is discontinuous, occurring in discrete elements or quanta Where an argument depends on so many intricate hypotheses and analogies the possible interpretations of the mathematical formulæ are to some extent uncertain, but it would appear that Professor Planck's equations are not necessarily inconsistent with the view above expressed, that both emission and absorption of

radiation are continuous, and that his *elementa quanta*, the energy of which varies with their frequency, should rather be identified with the molecules of caloric, representing the conversion of the electro-magnetic energy of radiation into the form of heat, and possessing energy in proportion to their temperature

Among the difficulties felt rather than explicitly stated, in regarding entropy or caloric as the measure of heat quantity, is its awkward habit of becoming infinite, according to the usual approximate formulæ, at extremes of pressure or temperature If caloric is to be regarded as the measure of heat quantity, the quantity existing in a finite body must be finite, and must vanish at the absolute zero of temperature In reality there is no experimental foundation for any other conclusion According to the usual gas formulæ, it would be possible to extract an infinite quantity of caloric from a finite quantity of gas by compressing it at constant temperature It is true that (even if we assumed the law of gases to hold up to infinite pressures, which is far from being the case) the quantity of caloric extracted would be of an infinitely low order of infinity as compared with the pressure required But, as a matter of fact, experiment indicates that the quantity obtainable would be finite, although its exact value cannot be calculated owing to our ignorance of the properties of gases at infinite pressures In a similar way, if we assume that the specific heat as ordinarily measured remains constant, or approaches a finite limit at the absolute zero of temperature, we should arrive at the conclusion that an infinite quantity of caloric would be required to raise the temperature of a finite body from 0° to 1° absolute The tendency of recent experimental work on specific heats at low temperatures, by Tilden, Nernst, Lindemann, and others, is to show, on the contrary, that the specific heats of all substances tend to vanish as the absolute zero is approached and that it is the specific capacity for caloric which approaches a finite limit The theory of the variation of the specific heats of solids at low temperatures is one of the most vital problems in the theory of heat at the present time, and is engaging the attention of many active workers Professor Lindemann, one of the leading exponents of this work, has kindly consented to open a discussion on the subject in our Section We are very fortunate to have succeeded in securing so able an exponent and shall await his exposition with the greatest interest For the present I need only add that the obvious conclusion of the caloric theory bids fair to be completely justified

A most interesting question, which early presented itself to Rumford and other inquirers into the caloric theory of heat, was whether caloric possessed *weight* While a positive answer to this question would be greatly in favour of a material theory, a negative answer, such as that found by Rumford, or quite recently by Professor Poynting and Phillips, and by Mr L Southerns working independently, would not be conclusively against it The latter observers found that the change in weight, if any, certainly did not exceed 1 in 10^8 per 1° C If the mass of a molecule of caloric were the same as that generally attributed to an electron, the change of weight, in the cases tested, should have been of the order of 1 in 10^7 per 1° C, and should not have escaped detection It is generally agreed, however, that the mass of the electron is entirely electro-magnetic Any such statement virtually assumes a particular distribution of the electricity in a spherical electron of given size But if electricity itself really consists of electrons, an argument of this type would appear to be so perfectly circular that it is questionable how much weight should be attached to it If the equivalent mass of an electron in motion arises solely from the electro-magnetic field produced by its motion, a neutral corpuscle of caloric should not possess mass or energy of translation as a whole, though it might still possess energy of vibration or rotation of its separate charges For the purpose of mental imagery we might picture the electron as the free or broken end of a vortex filament, and the neutral corpuscle as a vortex ring produced when the positive and negative ends are united, but a mental picture of this kind does not carry us any further than the sphere coated with electricity, except in so far as either image may suggest points for experimental investigation In our ignorance of the exact mechanism of gravity it is even conceivable that a particle of caloric might possess mass without possessing weight, though, with the possible exception of the electron, nothing of the kind has yet been demonstrated In any case it would appear that the mass, if any,

associated with a quantity of caloric must be so small that we could not hope to learn much about it by the direct use of the balance.

The fundamental property of caloric, that its total quantity cannot be diminished by any known process, and that it is not energy, but merely the vehicle or carrier of energy, is most simply represented in thought by imagining it to consist of some indestructible form of matter. The further property, that it is always generated in any turbulent or irreversible process, appears at first sight to conflict with this idea, because it is difficult to see how anything indestructible can be so easily generated. When, however, we speak of caloric as being generated, what we really mean is that it becomes associated with a material body in such a way that we can observe and measure its quantity by the change of state produced. The caloric may have existed previously in a form in which its presence could not be detected. In the light of recent discoveries we might suppose the caloric generated to arise from the disintegration of the atoms of matter. No doubt some caloric is produced in this way, but those corpuscles that are so strongly held as to be incapable of detection by ordinary physical methods require intense shocks to dislodge them. A more probable source of caloric is the æther, which, so far as we know, may consist entirely of neutral corpuscles of caloric. The hypothesis of a continuous æther has led to great difficulties in the electro-magnetic theory of light and in the kinetic theory of gases. A molecular, or cellular-vortex, structure appears to be required. According to the researches of Kelvin, Fitzgerald, and Hicks, such an æther can be devised to satisfy the requirements of the electro-magnetic theory without requiring it to possess a density many times greater than that of platinum. So far as the properties of caloric are concerned, a neutral pair of electrons would appear to constitute the simplest type of molecule, though without more exact knowledge of the ultimate nature of an electric charge it would be impossible to predict all its properties. Whether an æther composed of such molecules would be competent to discharge satisfactorily all the onerous functions expected from it may be difficult to decide, but the inquiry, in its turn, would probably throw light on the ultimate structure of the molecule.

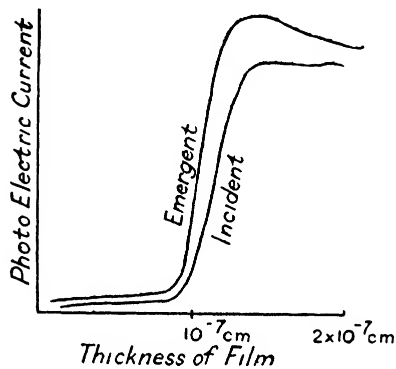
Without venturing too far into the regions of metaphysical speculation, or reasoning in vicious circles about the nature of an electric charge, we may at least assert with some degree of plausibility that material bodies under ordinary conditions probably contain a number of discrete physical entities, similar in kind to X rays or neutral corpuscles, which are capable of acting as carriers of energy, and of preserving the statistical equilibrium between matter and radiation at any temperature in virtue of their interchanges with electrons. If we go a step further and identify these corpuscles with the molecules of caloric, we shall certainly come in conflict with some of the fundamental dogmas of the kinetic theory, which tries to express everything in terms of energy, but the change involved is mainly one of standpoint or expression. The experimental facts remain the same, but we describe them differently. Caloric has a physical existence, instead of being merely the logarithm of the probability of a complexion. In common with many experimentalists, I cannot help feeling that we have everything to gain by attaching a material conception to a quantity of caloric as the natural measure of a quantity of heat as opposed to a quantity of heat energy. In the time at my disposal I could not pretend to offer you more than a suggestion of a sketch, an apology for the possibility of an explanation, but I hope I may have succeeded in conveying the impression that a caloric theory of heat is not so entirely unreasonable in the light of recent experiment as we are sometimes led to imagine.

The following Papers were then read:—

1. *The Heating Effect of Radium Emanation and its Products.* *By* Professor E. RUTHERFORD, *F.R.S.*, *and* H. ROBINSON.

2 *The Photo-electric Properties of Thin Metallic Films*
By J ROBINSON

The dissymmetrical photo-electric effect is observed for metallic films of the order of thickness 10^{-7} cm. For very thin films the emergent current is greater than the incident. The same statement applies to the velocities of the photo-electric electrons. As the thickness of the film increases, a certain thickness is found which makes the emergent current equal to the incident. It is found that at the same thickness the emergent velocity equals the incident velocity.



The actual magnitude of the photo-electric current for platinum (either incident or emergent) depends on the thickness of the film in a way shown by the accompanying curve. At a certain critical thickness (10^{-7} cm) both the incident and the emergent effects increase rapidly about thirty times At this thickness also we have an alteration of the ratio $\frac{\text{emergent}}{\text{incident}}$ currents For films thinner than 10^{-7} cm this ratio is constant. At this thickness the ratio begins to decrease as the film increases in thickness.

At the same thickness we have also two other phenomena —

(*a*) The photo-electric velocities suffer a sudden change [1] As the thickness of film increases through 10^{-7} cm, the velocities diminish to about one-third of their previous value

(*b*) The specific resistance alters rapidly.

The photo-electric effects at this thickness can be explained on the view that the photo-electric electrons may be produced in one of two ways —

(*a*) Directly by light from molecules of the metal these we will call primary electrons

(*b*) By primary electrons colliding with molecules and producing secondary electrons.

If the thickness 10^{-7} cm is of the order of the mean free path of the electrons, then for films thinner than 10^{-7} cm. we get only primary electrons which have fairly large velocities. For films thicker than 10^{-7} cm. we get both primary and secondary electrons whose velocities are necessarily diminished.

[1] Dike, *Phys. Rev.*, July 1912.

3 *On the Discharge of Ultra-violet Light of High-speed Electrons.* *By* Professor R A. MILLIKAN

The ultra-violet light emanating from a spark source is able under suitable conditions to impart to electrons an initial velocity of at least 500 volts, while the velocities imparted under the same circumstances by a quartz-mercury lamp are never found to exceed 6 volts

An explanation of this difference is sought in the enormous instantaneous intensity of the light from a spark source, notwithstanding the fact that previous work has seemed to show an independence of initial velocity and intensity

4 *The Presence of Radium in the Chromosphere* *By* F W DYSON, *F R S*

5 *The Number of the Stars, and their Bearing on Stellar Distribution* *By* Dr S CHAPMAN.

6 *The Law of Equivoluminal Oscillations in Metals* *By* Professor W PEDDIE.

FRIDAY, SEPTEMBER 6.

Discussion on the Scientific Theory and Outstanding Problems of Wireless Telegraphy

(1) *Introductory Remarks* *By* Professor J A FLEMING, *D Sc* , *F R S*

The chief object of this discussion being to consider matters of great scientific interest in connection with wireless telegraphy which are still imperfectly explained, a brief description may first be given of the usual apparatus of radiotelegraphy in the large majority of stations due to the inventions of Marconi, Lodge, and many others Apart from Marconi's improvements in the metallic filings coherer of Hughes, Branly, and Lodge, the important element in the arrangements by which in 1896 he applied purely scientific knowledge of Hertzian electric waves to practical electric wave or radio-telegraphy was the introduction of the long, nearly vertical, aerial wire as a radiator, combined with a metal plate above or buried in the earth as the balancing capacity In this wire, high-frequency oscillations are created, originally by using the wire itself as one electrode of an air-condenser and the earth as the other, but later on by inducing oscillations in the wire by means of the dead-beat or oscillatory discharge in another condenser circuit including a spark-gap coupled to the air wire-circuit. Although enormous ingenuity has been expended in improving or varying every element in the appliances, we can say that, with the exception of a small number of stations using the Duddell-Poulsen arc generator, nearly all the practical wireless telegraphy in the world is at present (1912) conducted by the following apparatus At each station there is a transmitter which comprises three elements —

1 A source of high E M F which may be a continuous-current dynamo and storage battery, an alternator and transformer, or a battery and induction coil giving continuous, alternating, or interrupted high-tension E M F
2 A condenser in which the generator stores an electric charge to be suddenly released when a certain potential is attained across a spark-gap in the form of an electric discharge passing through a coil in series with the condenser.

3 An open or radiative circuit coupled to the condenser circuit, comprising an antenna or arrangement of elevated air-wires, a balancing capacity or counterpoise often buried in the earth, the two being connected through an adjustable inductance-coil

At the receiving station we have also three elements —

1 An absorbing antenna, by which the radiation from the transmitter is picked up, creating in it high-frequency oscillations
2 A condenser circuit having variable capacity and inductance coupled to the antenna and syntonised to it
3 Some form of oscillation detector, connected in series or parallel with the above condenser, which is affected by the oscillations, and sets in operation a recording or indicating device which makes a visible or audible signal

Generally speaking, at any one station the radiating and absorbing antennæ are one and the same, and used for both purposes alternately, and each station has both transmitting and receiving apparatus The functions are, however, not identical What is required in the transmitting antenna is a certain height and also free or insulated ends In the receiving antenna, not only height but surface is required, although this antenna can be laid parallel with and close to the earth, and earthed at both ends, but provided it is half a wave-length in length it will still absorb a considerable amount of energy from electric waves arriving in its own direction

In nearly all cases these oscillations are excited in the antenna by the intermittent discharge of a condenser They are, therefore, damped or decadent trains of free oscillations, separated by intervals of silence The group frequency, as it is called, or number of the trains of oscillations, is now usually five hunded to one thousand, since when using the telephone as a receiver the group frequency is preferably that frequency for which the telephone is most sensitive Each train of oscillations may comprise thirty, fifty, or one hundred oscillations having the antenna frequency The antenna is, therefore, set in electrical vibration, so that trains of electric currents run up and down it intermittently, say five hundred times a second, each train consisting of fifty or more decadent oscillations, whilst each oscillation or single current occupies a time between one fifty-thousandth of a second and one two-millionth of a second in its complete two-and-fro cycle

These high-frequency currents in the antenna are created by the induction of a nearly dead beat, or else an oscillatory discharge of a condenser In small installations the condenser is a collection of Leyden jars, or, more conveniently, glass plates coated with thin sheet zinc or tin, the plates being immersed in a metal or stoneware box of oil

From the transmitting antenna electric radiation takes place

An extremely small fraction of the whole radiated energy is picked up by the receiving antenna In this latter we have currents created which are measured in microamperes, or at best in fractions of a milliampere If the receiving antenna is properly tuned to a closed condenser circuit inductively coupled to it, the energy picked up by the receiving antenna accumulates in the associated condenser circuit

In this last we then have feeble currents circulating which imitate in mode of variation those of the distant transmitting antenna To detect them it is now most usual to employ a telephone in series with some form of current rectifier, which is shunted across the condenser in the closed secondary receiving circuit, or else some form of current operated detector, such as Marconi's magnetic detector, which is placed in the condenser circuit

If we merely connect a telephone across the condenser circuit no sound will be produced in it, because the frequency of the current oscillations in the receiving condenser circuit is too high to affect a telephone If, however, we insert some device in series with the telephone which acts like a valve it will rectify the groups of oscillations into prolonged gushes of electricity in one direction, which, coming at the rate of the much lower spark frequency, say about five hundred or one thousand per second, create in the telephone a shrill sound. As these groups are interrupted at the sending station in accordance

with the Morse signals, the receiving operator hears long or short musical sounds, which he can interpret into the letters of the alphabet

The wireless message is thus picked up at the receiving station by hearing telephonic sounds due to a greater or less number of trains of high frequency oscillations in the transmitting antenna corresponding to *dashes* or *dots* in the Morse alphabet

These long or short groups of oscillations in the transmitting antenna create similar groups in the receiving antenna, which, when rectified, cause gushes of electricity in one direction through the telephone, and therefore make sounds like ticks or musical notes of long or short duration The pitch of this note is the frequency of the spark at the sending station

As long as short distances only were being covered by the use of the above apparatus a sufficiently satisfactory explanation of it was found in the properties of Hertzian waves When, however, Mr Marconi in 1901 sent the first signals across the Atlantic, and later achieved the feat of signalling 6,000 miles from Ireland to South America, the question arose how such waves, if they are true Hertzian waves, are propagated a quarter of the way round the earth The mathematical investigations of Professor Macdonald, Lord Rayleigh, the late Professor H Poincaré, and of Dr Nicholson seem to have proved that diffraction alone will not account for the phenomenon, even although the electric waves used, as by Marconi, have a wave length of nearly four miles, or the two-thousandth part of the earth diameter Another theory has been developed by Professor A Sommerfeld, starting from an assumption that the usual earthed transmitter may be regarded as a Hertzian oscillator at the boundary of two dielectrics of different nature His theory leads to the conclusion that there are not only space-waves (*Raumwellen*) in these media, but also surface-waves (*Oberflachenwellen*) at the boundary surface, and that these latter vary in amplitude inversely as the square root of the distance, and are sufficiently feebly damped in a horizontal direction to be propagated long distances, irrespective of irregularities of surface Hence they are not affected by earth curvature Objections have been raised to Sommerfeld's theory on the ground that these surface-waves have not been experimentally demonstrated, but it is evident that they resemble the surface-waves which can be produced on sheets of metal A third theory of long-distance electric-wave propagation has been based upon the ionisation of the atmosphere

Dr Eccles has shown that in a medium containing free ions of a certain kind the electric-wave velocity may be greater than that of the wave in the same dielectric un-ionised Hence the upper part of a wave surface travelling over the earth may have a greater velocity than the lower part if it should happen that the upper atmosphere is ionised, as it most probably is, by ultra-violet light The wave may, therefore, follow round the earth's curvature to a greater or less extent

Closely connected with this is another imperfectly solved problem in connection with long-distance radiotelegraphy, viz , the reason for the inhibiting effect of daylight An explanation has been sought in the discharging effect of light upon the antenna, and also in the absorption of wave energy produced by atmospheric ionisation It can, however, be shown that no atmospheric conductivity yet measured at earth-level, or some moderate height, is sufficient to produce the absorption required by observation An explanation may be sought in the refraction of the long electric waves by the varying dielectric constant produced by ionisation of the atmosphere by ultra-violet light at various levels of the atmosphere, which would curve the ray more or less out of agreement with the earth's curvature and hence reduce its range

There are many phenomena, such as the greatly reduced signalling distance at dawn and dusk and the inequality in signalling distance in a north-south and east-west direction observed by Mr Marconi, which have not yet been explained on any theory Other questions which may be thrown down for discussion are those of the theory of directive antennæ, such as those of Marconi and Bellini and Tosi, and also the location of the direction of the arriving radiotelegraphic waves

The problem of radiotelephony seems in a fair way of solution by means of improved arc-generators and of high-frequency alternators Also practical improvements have lately been made in recording by various means the radio-

telegraphic signals, and substituting for the simple telephonic receiver and rectifier or magnetic detector a visual signal or supplementing it by a loud-sounding call

(ii) *On Wireless Telegraphy* *By* Professor Dr A SOMMERFELD

Der Verfasser versucht von seinem theoretischen Standpunkte aus, die verschiedenen von Professor Fleming formulirten Fragen zu beantworten

Er halt an der Hoffnung fest, dass die Maxwell'schen Gleichungen unter einfachsten Annahmen uber das Verhalten der Erde und Luft im Stande sind, von den praktischen Ergebnissen der drahtlosen Telegraphie Rechenschaft zu geben Diffraction, Oberflachenwellen und Hertz'sche Raumwellen lassen sich in der strengen Losung der Maxwell'schen Gleichungen nicht von einander trennen, sind veilmehr durch die Bedingungen an der Grenze zwischen Luft und Edre miteinander notwendig verknupft

Eine von dem Verfasser veranlasste Untersuchung von H W March ist dahin zu berichtigen, dass zu der von March ursprunglich angegebenen Formel ein exponentieller Zerstreuungsfaktor hinzutritt, der dieselbe Form hat, wie in den Untersuchungen von Poincaré und Nicholson Bei grossen Wellenlangen ist dieser Faktor nicht so gross, dass er, wie man angenommen hat, die praktische Ueberwindung der Erdkrummung unmoglich macht Vielmehr scheint er mit den Messungen von Austin der Grossenordnung nach ubereinzustimmen Die Mitwirkung von Oberflachenwellen kommt in dem March'schen Resultat ebenfalls zum Ausdruck

Der Unterschied der Ausbreitung uber Land und Wasser durfte durch die Rechnungen des Verfassers (Ann 28) erklart sein Die Ionisation der oberen Luftschichten kann die Ueberwindung der Erdkrummung nicht erklaren Die Theorie des gerichteten Senders von Horschelmann scheint dem Verfasser zuverlassig

(iii) *On certain Phenomena accompanying the Propagation of Electric Waves over the Surface of the Globe* *By* W H ECCLES, *D Sc*

The purpose of this paper was to describe some of the phenomena met with in the transmission of electric waves, natural and artificial, over great distances, and to examine how far they may be accounted for by the ionisation of the air through which the waves travel The importance in this connection of the natural ionisation of the air has only recently had attention drawn to it in a paper read by the author before the Royal Society in June In this paper it was shown that the velocity of electric waves through ionised air exceeds their velocity through un-ionised air by a percentage proportional to the concentration of the ions Assuming that the ionisation due to solar radiation increases with increase of height above the earth's surface, it follows that a vertical wave-front will tend to tilt forward as it travels It is found that the consequent curvature of the trajectory of waves travelling nearly horizontally will work out at about the curvature of the earth for quite reasonable values for the concentration of the ions The trajectory is more curved the lower the frequency of the waves, being, in fact, inversely proportional to the square of the frequency at high levels, but probably varying much less rapidly with frequency at the low levels In order to account for the great difference between day and night transmission it seems necessary to suppose that there exists in the upper atmosphere a permanently ionised layer that is not dependent on solar radiation for its maintenance—a suggestion due to Heaviside Some justification for this assumption was adduced in the present paper from facts quite distinct from wireless telegraphy Taking this hypothesis with the hypothesis of refraction by ionised air, many phenomena can be explained without appeal to the principles of diffraction or to absorption in the air or by the earth's surface

Some of the most remarkable and impressive phenomena yet brought to light by wireless telegraphy are the fluctuations of signals and of strays at twilight, in the night, or during an eclipse of the sun These especially were discussed in the paper Many of the observed facts can be explained tolerably well by aid of the hypotheses described.

A number of observations made by the writer during the past three years, and during the recent eclipse of the sun, on the natural electric waves ('strays') received in London, lead to suggestions as to the sources of the strays received in England in, at any rate, the part of the year most free from local lightning storms. In addition a method of using the strays for determining the absorption of the waves was described.

DEPARTMENT OF GENERAL PHYSICS

The following Papers were read:—

1. *Exhibition of New Phenomenon of Doubly-refracting Crystals.* *By* Professor S. P. THOMPSON, *F.R.S.*

2. *On some Iridescent Films.* *By* Lord RAYLEIGH, *O.M., F.R.S.*

3. *The Critical Velocity of Flow of Mercury in Small Tubes.* *By* Professor E. G. COKER, *M.A.*

The flow of mercury in tubes at low velocities has been studied by Koch and others with a view of determining the viscosity at different temperatures, but no experiments appear to have been made at high velocities at which the flow may be turbulent. In the present experiments both stream-line motion and turbulent flow were the subject of experiment in steel tubes having a range of bore from 0.04 cm. to 0.16 cm., and at temperatures between 0° C. and 100° C.

The apparatus used was described in the paper, and differs in some respects from that usually employed in viscosity determinations, particularly with respect to the method of maintaining a constant head of mercury and the measurement of the fall of pressure due to flow.

The experimental values obtained show that the flow tends to become unstable beyond a critical velocity depending on the bore of the tube and the temperature of the mercury.

Although in general stream-line flow, in favourable circumstances, persists beyond this critical limit, the lowest velocity at which turbulent motion may commence is found to vary inversely as the diameter of the pipe and directly as the viscosity.

4. *Some New Spinning Tops.* *By* Dr. J. G. GRAY.

DEPARTMENT OF MATHEMATICS

The following Papers were read:—

1. *An Apparatus for the Solution of Equations of the* n*th Degree.* *By* Professor W. PEDDIE, *F.R.S.E.*

2. *Sur une nouvelle machine algébrique.* *Par* A. GÉRARDIN.

Cette machine sert pour la décomposition des grands nombres, pour la résolution en entiers des équations indéterminées de degres supérieurs ou des congruences.

Elle est basée sur la simple étude, même automatique de bandes périodiques de résidus dont nous allons donner un exemple.

Nous représentons un résidu par une case blanche ou un zéro et un non résidu

par l'unité ou par une case noire Si nous avons étudié p modules, nous aurons p bandes différentes, et la *condition necessaire* pour avoir une solution, est que l'on trouve une bande verticale entièrement blanche, entre certaines limites Au lieu d'avoir des bandes indéfinies, notre machine actuelle comporte p bandes presque égales d'une longueur pratique de trois mètres environ enroulees sur deux cylindres entraîneurs égaux, dont je vais donner le schéma au tableau Le système est equilibre, et il est facile d'ajouter un mécanisme simple permettant d'étudier normalement cent lignes à la seconde On pourra examiner ainsi quelques millions de nombres par jour, et résoudre des questions depuis longtemps sans réponse

Nous ramenons d'abord tout probleme indeterminé à une équation de la forme

$$a+bx+cx^2+dx^3 \ . \ . \quad =y^n$$

et à l'aide des nombres premiers successifs, nous n'avons qu'à former la bande relative à chacun d'eux Exemple

$$2047=(6x+5)\ (6y+5)$$

On aura, avec p inconnue auxiliare

$$x+y=6p+5,\ xy=52-5p,\ p\leqq 10$$

$$36p^2+80p-183=z^2$$

On voit que p est pair, d'ou la bande		0 1 0 1 0 1 0 1 0 .
module 3	$p\equiv 0, 2$,,	0 1 0 0 1 0 0 1 0
mod 5	$p\equiv 2, 3$,,	1 1 0 0 1 1 1 0 0
	nombres réels	0 1 2 3 4 5 6 7 8 .

La première ligne blanche ou formée de zéros se trouve au nombre 2, c'est la solution cherchee,

$$p=2,\ x=3,\ y=14,\ 2047=23\times 89$$

J'ai trouvé rapidement pour y un nombre entier de neuf chiffres dans

$$n=\tfrac{1}{6}[(x+1)(x+2)(x+3)-6]=\tfrac{1}{2}(y+1)(y+2)$$

à propos des courbes osculatrices [1] Je ramène ce probleme à 3 équations de la forme

$$a+bx+cx^2+dx^3=z^2$$

La décomposition de M_{47}, nombre de Mersenne connu, demanderait 4 minutes

Théoriquement, la longueur seule du calcul automatique pourrait empêcher de décomposer des nombres énormes, nous ne résoudrons donc que ceux de formes spéciales ou ceux dont l'utilite nous serait signalée en Arithmétique Supérieure

Il est très difficile d'exposer plus de détails dans un espace si mesuré, mais je reste à la disposition de nos collègues anglais, pour explications

---

3 *On Mersenne's Numbers*

By Lieut -Colonel Allan Cunningham, *R E*

These are of form $M_q=(2^q-1)$, with q *prime*

Important progress has been made since last Report (1911), viz :—

$M_{71}=228479^*$ $48544121^\dagger$ $212885833^\dagger$; * due to the present writer (1909); † (both prime) due to Mr Ramesam, of Mylapore, India (1912).

M_{89}, composite according to Mersenne, and confirmed by Ed Lucas; but proved *prime* by R E Powers (America) and H Tarry (France) in 1911, and verified by E. Fauquembergue (France) in 1912.

$M_{173}\equiv 0$ (mod. 730753), found by the present writer in 1912.

Thereby three mistakes have now been proved in Mersenne's classification, viz, M_{67} proved *composite*, M_{61}, M_{89} proved *prime*

[1] Hermite, 'Cours d'analyse,' 1873, p 145.

This leaves still unverified only one (M_{257}) of Mersenne's supposed primes, and 14 out of his 44 supposed composites, viz, those given by

q=101, 103, 107, 109, 137, 139, 149, 157, 167, 193, 199, 227, 229, 241.

A complete list of all the possible prime divisors < one million of the 14 still unverified supposed composites has been prepared by M A Gérardin (of Nancy, France) and the author jointly (but working independently) These 'trial divisors' have been tested by the author up to that same limit without success; every trial divisor was tried twice.

MONDAY, SEPTEMBER 9

Joint Discussion with Section B on the Atomic Heat of Solids

(1) *The Atomic Heat of Solids at Low Temperatures*

By F A Lindemann, *Ph D*

If the ordinary principles of mechanics are admitted as governing the movements of atoms, equipartition of energy is bound to be attained, as has been shown by Maxwell, Boltzmann, Jeans, and others Therefore the atomic heat of a solid at constant volume should be exactly 3R

Planck has shown that the energy U of an electric charge capable of oscillating with frequency ν and in equilibrium with radiation of frequency ν and energy u per cm^3, is

$$U=\frac{3c^3u}{16\pi\nu^2}.$$

Therefore Rayleigh's formula

$$E_\lambda=\frac{2cRT}{N\lambda^4}$$

should be strictly accurate This is obviously false, as F_λ becomes ∞ for $\lambda=0$ According to Poincaré one is bound to find a similar formula if one assumes that an atomic collision is capable of representation by differential equations

Assuming that an oscillator can only emit definite, discontinuous quantums of energy, Planck showed that their magnitude is proportional to the frequency, and developed the formula

$$E_\lambda=\frac{2c^2h}{\lambda^5}\cdot\frac{1}{e^{\frac{ch}{\kappa\lambda T}}-1} \quad \text{or} \quad u=\frac{16\pi h\nu^3}{c^3}\cdot\frac{1}{e^{\frac{h\nu}{\kappa T}}-1}$$

where h is a new universal constant 6,55 10^{-27} erg sec, and κ is $\frac{R}{N}$ This formula appears to agree with experimental results

If a solid is composed of atoms held at a certain mean distance from one another by forces, whose presence is revealed by the phenomena of elasticity, &c, these atoms will act as oscillators, whose frequency is determined by the force holding them in equilibrium and by their mass If these atoms are electrically charged, as appears to be the case in salts which are strongly ionised in solution, they must contain the energy

$$U=\frac{3c^3}{16\pi\nu^3}u=\frac{3h\nu}{e^{\frac{h\nu}{\kappa T}}-1}$$

as there would otherwise be a continual leak of energy from matter to ether, or *vice versâ* The same holds good if the atoms are not charged, as in the diamond, for one can imagine them connected to charged atoms by a perfect

conductor of heat Therefore, as Einstein pointed out, the atomic heat of N atoms ought to be

$$\frac{dU}{dT} = c_v = \frac{\left(\frac{h\nu}{\kappa T}\right)^2 e^{\frac{h\nu}{\kappa T}}}{\left(e^{\frac{h\nu}{\kappa T}} - 1\right)^2}$$

This formula is only approximately correct, and fails altogether if one inserts the true frequencies These may be calculated from the Reststrahlen, from the compressibility, density, and atomic weight, or from the melting-point, density, and atomic weight The last two methods are not nearly as exact as the first

According to Nernst and Lindemann the atomic heat of the metals, of the diamond, NaCl, KCl, NaBr, and KBr, may be accurately represented by

$$c_v = {}^3/_2 R \left\{ \frac{\left(\frac{h\nu}{\kappa T}\right)^2 e^{\frac{h\nu}{\kappa T}}}{\left(e^{\frac{h\nu}{\kappa T}} - 1\right)^2} + \frac{\left(\frac{h\nu}{\kappa T}\right)^2 e^{\frac{h\nu}{2\kappa T}}}{\left(e^{\frac{h\nu}{2\kappa T}} - 1\right)^2} \right\}$$

where ν is in the case of the salts the exact frequency as found by Rubens by means of the Reststrahlen The second term in the brackets is difficult to explain As it leads one to expect reflection an octave below the Reststrahlen, where the salts are transparent it has been suggested that it represents potential whilst the first term denotes kinetic energy That this simple formula is only valid for substances which crystallise in the regular system, suggests that the slow vibrations may not be capable of causing Reststrahlen on account of the grouping of the positive and negative charges

A fact that emerges clearly is that the free electrons, if there are any, can only have a very small specific heat, for the atomic heats of conductors and non-conductors may be represented by practically identical curves

Further it may be shown that Nernst's theorem is a consequence of the fact that the atomic heats are infinitely small at the absolute zero

(ii) *On an Hypothesis as to the Nature of Planck's Quantum of Action* By G E Gibson, *Ph D*

One of the chief difficulties in Planck's original theory of radiation is the assumption of a discontinuous absorption and emission of energy by the resonators Such a discontinuity is inconsistent with Maxwell's equations, on which the fundamental relation between the energy, U, of a resonator and the energy density, u, of the surrounding field, viz —

$$U = \frac{c^3 u}{8\pi\nu^2} \qquad (1)$$

is based.

In a former paper[1] the author suggested an hypothesis by means of which this difficulty might be overcome Let us suppose that the discontinuity is confined solely to the collisions between the molecules with which the resonators are connected, so that during the time between collisions the resonators are subject to the ordinary laws of electrodynamics Let us further suppose that the discontinuity due to the collisions is such that the energy of the resonator immediately after the collision is an integral multiple of a certain quantity ϵ, whose magnitude will be specified later

It can be shown [2] that, in all cases open to experimental investigation, the logarithmic decrement of an electron, bound to its position of equilibrium by quasi-elastic forces, is so small that its loss or gain of energy during the free time of a molecule can only be a very small fraction of ϵ.

Let us consider the forced vibrations of a resonator in the time between two collisions.

[1] *Verh. der Deutsch. Phys. Ges.*, xvi., p. 104, 1912.
[2] *Loc. cit.*

The electrical moment $Z(t)$ of a resonator vibrating parallel to the Z axis is determined by the equation[3]

$$16\pi^4\nu_0^3 Z + 4\pi^2\nu_0^2\ddot{Z} - 2\sigma\dddot{Z} = 3\sigma c^3 E_z \quad . \quad . \quad . \quad . \quad (2)$$

where ν_0 is the frequency of the resonator, σ its logarithmic decrement, c the velocity of light and E_z the Z component of the electric intensity of the heat radiation at the resonator.

Writing E_z as a Fourier series for the time τ between two collisions,

$$E_z = \sum_n^{o,\infty} C_n\left(\cos\frac{2\pi n t}{\tau} - \theta_n\right) \quad . \quad (3)$$

and putting $\frac{n}{\tau} = \nu$ we obtain the complete integral of (2) in the form

$$Z(t) = Z_o(t) + Z_n(t)$$

$$= Pe^{-\sigma\nu_o t}\cos(2\pi\nu_o t - \theta) + \frac{3c^3}{16\pi^3}\sum_n^{o\,\infty}\frac{C_n\sin\gamma_n}{\nu^3}\cos(2\pi\nu t - \theta_n - \gamma_n) \quad . \quad . \quad (4)$$

where
$$\cot\gamma_n = \frac{\pi\nu_o(\nu_o^2 - \nu^2)}{\sigma\nu^3}$$

The rate at which energy is absorbed by the resonator is

$$E_z\dot{Z} = -\nu_o e^{-\sigma\nu_o t}\left\{\sigma\cos(2\pi\nu t - \theta_o) + 2\pi\sin(2\pi\nu_o t - \theta_o)\right\} P E_z + E_z\dot{Z}_n \quad (5)$$

Out of all the resonators which suffered the last collision at the time $t = o$ let us select a group in which, at the time t, P and E_z have the same value for every resonator in the group

The part of the mean value of $E_z\dot{Z}$ or this group, which depends on the first term of (5), vanishes if we assume that all values of θ_o are equally probable

But all the resonators can be arranged in groups in a similar manner, so that the mean value of the rate of absorption is independent of the free vibrations

The mean rate at which energy is absorbed by a very large number of resonators, N, is therefore

$$N Q_a = \frac{3c^3 N}{16\pi^2}\sum_n^{o\,\infty}\frac{C_n^2\sin^2\gamma_n}{\nu^3} \quad (6)$$

Reasoning in the same way as Planck,[4] we arrive at the equation

$$N Q_a = \frac{2c^2\sigma N}{\nu_o}K_\nu \quad . \quad . \quad . \quad (7)$$

where K_ν is the intensity of the monochromatic plane polarised radiation of frequency ν

The mean emitted energy can be calculated in a similar manner A resonator whose energy is $m\epsilon$ emits per second, on the average the energy

$$Q_m = 2m\epsilon\sigma\nu_o \quad (8)$$

Out of N resonators

$$N_m = N\left(e^{-m\frac{\epsilon}{\kappa T}} - e^{-(m+1)\frac{\epsilon}{\kappa T}}\right) \quad . \quad (9)$$

vibrate with the energy $m\epsilon$ at the temperature τ

The total energy emitted per second by the N resonators is therefore

$$\sum_m^{o,\infty} Q_m N_m = 2\sigma\nu_o N\frac{\epsilon}{e^{\frac{\epsilon}{\kappa T}} - 1} \quad . \quad . \quad . \quad . \quad (10)$$

[3] Planck, 'Theorie d. Warmestrahlung,' p 113.
[4] 'Theorie d. Warmestrahlung,' p 122 (1906).

If the N resonators are to be in equilibrium with the external radiation they must absorb as much energy per second as they emit. The condition for equilibrium is therefore by (7) and (10)

$$K_\nu = \frac{\nu^2}{c^2} \frac{\epsilon}{e^{\frac{\epsilon}{\kappa T}} - 1} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Comparing this with Wien's law in the form

$$K_\nu = \frac{\nu^3}{c^2} F\left(\frac{\nu}{T}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

we see that ϵ must be proportional to ν

Putting

$$\epsilon = h\nu \quad . \quad . \quad (13)$$

we arrive at Planck's law

$$K_\nu = \frac{h\nu^3}{c^2} \frac{1}{e^{\frac{h\nu}{\kappa T}} - 1} \quad . \quad . \quad (14)$$

Department of General Physics

The following Papers were read —

1. *The Law of Fall of a Drop through Air at Reduced Pressures and a Redetermination of e* By Professor R. A Millikan.

A law of fall of the form

$$v = \frac{2}{9} \frac{ga^2(\sigma - \rho)}{\mu} \left\{1 + A\frac{l}{a}\right\} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

is found to hold accurately so long as $\frac{l}{a} < 4$, but beyond that limit it loses its applicability, and the term in brackets must be replaced by

$$\left\{1 + A\frac{l}{a} + Bc^{-C\frac{a}{l}}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

in which A, B, and C are all positive constants. If l is obtained from the Boltzmann formula

$$\mu = 3502\, mn\bar{c}l,$$

then A is found to have the value 0·874, B the value 0·35, and C the value 1·7.

The accurate evaluation of the constant A makes possible a determination of e which has a probable error of no more than one-tenth per cent. This value is

$$e = 4\ 775 \times 10^{-10} \text{ E S. Unit.}$$

---

2 *On the Intensity of the Earth's Penetrating Radiation over Land and Large Bodies of Water.* By Professor J C McLennan.

---

3 *The Origin of the Beta and Gamma Rays from Radio-active Substances* *By* Professor E RUTHERFORD, *F R S*

4 *On a Conductivity imparted to Liquid Air by Alpha Rays* *By* Professor J C McLENNAN

5 *Magnetic Disturbances, Sun-Spots, and the Sun's Corona* *By* Rev A L CORTIE, *S J , F R A S*

1 Curves for the period 1898-1911 are compared of mean daily disc-area of sun-spots, mean daily range of declination, and horizontal force, and yearly numbers of great and moderate magnetic disturbances The data are contained in Father Sidgreaves' yearly reports of the Stonyhurst Observatory There is a general accord in the curves, but there are noticeable discrepancies The sun-spot area and the magnetic declination rose to a maximum in 1905, fell in 1906, and rose again to a subsidiary maximum in 1907 The horizontal force, and the numbers of magnetic storms, moderate and great, rose steadily from 1905 to a maximum in 1907 From 1907 the sun-spot area declined, the fall from 1909 to 1911 being particularly rapid The number of great magnetic storms fell, but not so rapidly But the rapid fall of the sun-spot curve, 1909-11, was accompanied by a marked rise in declination, horizontal force, and moderate magnetic disturbances The mean daily frequency of prominences (Kodaikanal) rose steadily from 1905 to 1910, the profile-area was at a maximum in 1908 In September 1909 a magnetic storm of exceptional violence occurred Six other great storms occurred in September and October of the same year The recovery of magnetic activity was heralded by these great storms The magnetic storms occurred near the autumnal equinox. All the bigger sun-spots of September and October 1909 were confined within a belt of about 10° each side of the solar equator

2 The monthly numbers of the great and very great magnetic storms for twenty-three years, 1889-1911, exhibit decided maxima near the equinoxes At such times the spot zones appear parallel to the plane of the ecliptic When the earth moves across the plane of the sun's equator great magnetic storms are more frequent The coronal streamers are long, and are mainly confined to regions adjoining the solar equator at periods of sun-spot minima At such periods the prominences are also fewer, and their regions fall towards the equator The long streamers of the solar corona are associated with the regions of prominence activity, while shorter plumed streamers—*e g*, 1893, 1901, 1905—radiate from sun-spot centres A series of spots and prominences occurring at frequent intervals would cause such streamers to be maintained for several solar rotations Eclipse photographs—*e g* , 1889, 1901—show that the general character is preserved for a considerable period By the cumulative action of successive accretions, clouds of charged particles, electrons, might be formed at the ends of the streamers It is suggested that the entry of the earth into such clouds occasions magnetic storms Several streamers of the solar corona, accompanied each by its attendant cloud of particles, would occasion two or more magnetic storms during the same passage of a spot, regarded as an index of general solar activity, across the sun's disc This accords with observed facts, fits in with the synodic periodicity of magnetic storms, and possibly obviates the great difficulties connected with the theory of the origin of magnetic storms as due to the projection of streams of particles from individual sun-spots The Zodiacal light extends from the sun along the ecliptic.

6 *A Machine for Drawing the Curves of Radio-active Changes* *By* F SODDY, *F R S*

DEPARTMENT OF MATHEMATICS

The following Papers and Report were read:—

1. *Arithmetical Factors of the Pellian Terms.* By Lieut.-Colonel ALLAN CUNNINGHAM, *R.E.*

Let (τ'_x, υ'_x), (τ_x, υ_x) be the xth solutions of the Pellian equations

$$\tau'^2 - 2\upsilon'^2 = -1, \qquad \tau^2 - 2\upsilon^2 = +1,$$

and let p, ω, ϵ denote an (odd) *prime*, an *odd number*, an *even number* respectively. Ed. Lucas has shown that

1. Every p divides into some υ_x.
2. Every $p = 8\varpi + 1$ divides into one of τ'_x, υ'_x, τ_x.
3. Every $p = 8\varpi + 3, 5, 7$ divides into τ_x, υ'_x, τ'_x respectively.

And, also that, in general, $\upsilon_x \equiv 0 \pmod p$,

$$\left.\begin{aligned} \text{where } x &= \frac{1}{n}(p-1), \text{ when } p = 8\varpi \pm 1 \\ x &= \frac{1}{n}(p+1), \text{ when } p = 8\varpi \pm 3 \end{aligned}\right\}, \text{ and } n = 2m.$$

New criteria are now given, showing when $n = 4m$, $8m$, $16m$, $32m$, and $3.2m$, depending only on the linear and quadratic forms of p, and showing a close analogy between the theories of

$$\upsilon_x \equiv 0 \pmod p, \text{ and } (2^x - 1) \equiv 0 \pmod p.$$

i. As to $n = 2\omega$, this happens when $p = 8\varpi + 3, 5, 7$.

$p = 8\varpi + 3$ gives $\upsilon_x \equiv 0$, $\tau_y \equiv 0$, where $x = \frac{1}{2}(p+1)$, $y = \frac{1}{2}x$.
$p = 8\varpi + 5$ gives $\upsilon_x \equiv 0$, $\upsilon'_y \equiv 0$, ,, $x = \frac{1}{2}(p+1)$, $y = \frac{1}{2}(x+1)$.
$p = 8\varpi + 7$ gives $\upsilon_x \equiv 0$, $\tau'_y \equiv 0$, ,, $x = \frac{1}{2}(p-1)$, $y = \frac{1}{2}(x+1)$.

ii. As to $n = 4m$, $8m$, &c., these require $p = 8\varpi + 1 = a^2 + b^2 = c^2 + 2d^2$, with $b = 4\beta$, $d = 2\delta$, and then give n as below—

p	d	n	p	b	d	n
$8\varpi + 1$	2ω	$4\omega'$	$32\varpi + 1$	8ϵ	8ω	$16\omega'$
,,	4ω	$8\omega'$	,,	8ω	8ϵ	$16\omega'$
$8\omega + 1$	4ϵ	$8\omega'$	,,	8ω	8ω	16ϵ
$16\omega + 1$	4ϵ	$16\omega'$				

iii. As to $n = 2.3m$, $p = 8\varpi \pm 1 = 3\varpi' + 1$ involves $p = G^2 + 6H^2$.
$p = 8\varpi \pm 3 = 3\varpi' - 1$ involves $p = 2G^2 + 3H^2$.

Then $n = 2.3m$ when—(and only when)—$H = 3h$.

iv. As to $n = 2.5m$, $2.7m$, &c., the criteria seem not to depend solely on the linear and quadratic forms of p.

v. As to the suffixes of τ', υ', τ, these are derivable from the suffix of υ (which is fundamental).

Let η', ξ', η, ξ be the *least* suffixes of τ', υ', τ, υ giving

$$\tau'_{\eta'} \equiv 0, \; \upsilon'_{\xi'} \equiv 0, \; \tau_\eta \equiv 0, \; \upsilon_\xi \equiv 0, \pmod p.$$

Then $\xi = \epsilon$ gives $\eta = \frac{1}{2}\xi$ always.

And, writing $b = 2^{\beta}\ \omega_1$, $d = 2^{\delta}\ \omega_2$, then

$$\begin{aligned}\xi &= \omega, \text{ with } \beta = \delta \text{ gives } \eta' = \tfrac{1}{2}(\xi + 1) \text{ usually}\\ \xi &= \omega, \text{ with } \beta \pm \delta \text{ gives } \xi' = \tfrac{1}{2}(\xi + 1) \text{ usually}\\ \xi &= \omega \text{ gives one of } \xi', \eta' = \tfrac{1}{2}(\xi + 1) \text{ always}\end{aligned}$$

vi The complete series of terms τ', v', τ, v divisible by p is given by

$$\tau'_{\eta' + m\xi} \equiv 0,\ v'_{\xi' + m\xi} \equiv 0,\ \tau_{\eta + m\xi} \equiv 0,\ v_{\xi + m\xi} \equiv 0,\ (\text{mod } p)$$

for all integral values of m, so that ξ is the *period of recurrence*

Thus ξ may be called the *Haupt-suffix* in $v_s \equiv 0$, just as ξ is called the *Haupt-exponent* in $2^s - 1 \equiv 0$ (mod p)

2 *The Algebraic Functions derived from the Permutations of any Assemblage of Objects* By Major P A MacMahon, F R S

3 *A Mode of Composition of Positive Quadratic Forms* By Professor E H Moore

The n–ary quadratic form

$$A \equiv \sum_{i,j}^{n} a_{ij} x_i x_j, \qquad (a_{ij} = a_{ji}),$$

with real coefficients a_{ij} is positive if, for real values of the n variables x, it takes on only positive or zero values From two n-ary quadratic forms A and B we obtain by multiplication of corresponding coefficients a third form C, the *inner composite* A × B of the two forms A and B

For this inner composition of n-ary quadratic forms the property of positiveness is invariant, *i e*, the inner composite of two positive forms A and B is likewise positive, otherwise expressed, the class of positive n ary quadratic forms is closed under the process of inner composition of forms For $n=1$ this theorem is that of the closure under multiplication of the class of non-negative real numbers Necessary and sufficient conditions in terms of the matrix (a_{ij}) of coefficients for the positiveness of the form A are well known, and for $n=2$ the theorem is readily proved by consideration of these conditions The theorem in its generality is readily proved by consideration (not of these conditions but) of the fact that a form is positive if and only if it is expressible as the sum of squares of a finite number of linear forms with real coefficients

Our theorem If A and B are positive forms, then A × B is a positive form, has as corollary and generalisation the theorem If A″, A′ − A″, B″, B′ − B″ are positive forms, then A′ × B′ − A″ × B″ is a positive form.

Similar theorems hold as to positive hermitian forms

These theorems have analogues and applications in the theory of linear integral equations.

4 *Proof of a General Theorem relating to Orders of Coincidence* By Professor J C Fields

Let $f(z, u) = u^n + f_{n-1}u^{n-1} + \quad + f_0 = 0$ be an equation in which the coefficients f_s are rational functions of z Suppose $(\tau)^{(\infty)}$ and $(\bar{\tau})'^{(\infty)}$ to be partial bases corresponding to the value $z = \infty$, the orders of coincidence furnished by these partial bases being complementary adjoint to the order 2 The general rational function of (z, u) conditioned by the partial basis $(\tau)'^{(\infty)}$ we shall designate by the notation

$$R\begin{pmatrix}1\\ z, u\end{pmatrix} = \sum_{t=1}^{n} \sum_{r} \gamma_{-r, n-t}\, z^{-r} u^{n-t}$$

In order that a rational function $\psi(z, u)$ should be conditioned by the partial basis

$(\bar{\tau})^{(\infty)}$ it is necessary and sufficient that the principal residue relative to the value $z=\infty$ in the product $R\left(\frac{1}{z}, u\right)\psi(z, u)$ should vanish. Furthermore, on taking the integer ι sufficiently large and equating to o, the principal residue in the product

$$\sum_{t=1}^{n}\sum_{r=-\iota}^{\iota+1}\gamma_{-r,n-t}z^{-r}u^{n-t}\sum_{t=1}^{n}\sum_{r=\iota+1}^{-\iota}a_{r-1,t-1}z^{r-1}u^{t-1},$$

it can be shown that we impose on the second factor the orders of coincidence furnished by the partial basis $(\bar{\tau})^{(\infty)}$ We thus impose on the coefficients $a_{r-1,t-1}$ in the second factor a number of conditions equal to the number of the coefficients $\gamma_{-r,n-t}$ in the first factor, which are arbitrary. Designating then by $2n(\iota+1)-\lambda$ and λ respectively the number of arbitrary coefficients in the first factor and the number of coefficients remaining arbitrary in the second factor after equating to zero the principal residue in the product, it is readily seen that we must have

$$2n(\iota+1)-2\lambda=\sum_{s=1}^{r\infty}(\bar{\tau}_s^{(\infty)}-\tau_s^{(\infty)})\nu_s^{(\infty)}.$$

We have, however, by hypothesis

$$\tau_s^{(\infty)}+\bar{\tau}_s^{(\infty)}=\mu_s^{(\infty)}+1+\frac{1}{\nu_s^{(\infty)}}, s=\quad,\ldots,r_\infty$$

We immediately derive

$$\lambda=n\iota+\sum_{s=1}^{r\infty}\tau_s^{(\infty)}\nu_s^{(\infty)}-\frac{1}{2}\sum_{s=1}^{r\infty}(\mu_s^{(\infty)}-1+\frac{1}{\nu_s}{(\infty)})\nu_s^{(\infty)}$$

This expression for λ then gives us the number of the independent conditions which must be imposed on the coefficients of the general rational function $R(\frac{1}{z}, u)$ of degree ι in z in order that it may have for the value $z=\infty$ the orders of coincidence furnished by the partial basis $(\tau)^{(\infty)}$—the integer ι being here taken not less than the highest degree in z which a rational function of (z, u) can have and yet possess the orders of coincidence here in question The corresponding result for any finite value $z=a$ can be immediately stated

---

5 *The Use of the Exponential Curve in Graphics*
By Dr H B Heywood

The properties of the exponential curve which are employed are shown in the following table, together with the graphical operations to which they may be applied —

				Error	
				Maximum Per cent	Average. Per cent.
1	$e^a\times e^b=e^{a+b}$	(Multiplication)	.. .	1	0 6
2.	$e^a-e^b=e^{a-b}$	(Division)	.	1	—
3	$(e^a)^n=e^{na}$	(Evolution, &c)	..	$\frac{1}{2}$	0 3
4	$\frac{d}{dx}e^x=e^{nx}$	(Differentiation)	.. ..	(15)	5
5.	$\int^b e^r dx = e^b - e^a$	(Integration) .	. ...	1	0 6

For carrying out the processes we use a templet of transparent celluloid, upon which is marked a graduated exponential curve

To perform the multiplication of two numbers, $y_1\times y_2$, we find with a pair of dividers the abscissæ, x_1 and x_2, which correspond to the ordinates y_1 and y_2. The product is the ordinate corresponding to the abscissa x_1+x_2

The second and third operations are carried out on similar lines

To perform a differentiation, that is to say, to find the measure of the slope of a curve at a given point, the templet, kept in a vertical position by means of a T-square, is adjusted so that the exponential curve touches the given curve at the given point. The ordinate of the exponential curve is then the measure of the slope

Integration is performed somewhat similarly The templet is fitted to sections of the curve whose area is to be measured in such a way that the two curves are in as good coincidence as possible The *area under the given curve is then equal to the difference of the extreme ordinates, corrected by a certain number of rectangles*

The practical value of the method rests on —

(1) Its simplicity and rapidity
(2) The fact that all the operations may be made purely graphical, the result being expressed as a length, and no calculation intervening
(3) Its relative accuracy

With regard to the last point, it may be added that of the test operations carried out by the author, the error for operations 1, 2, 3, and 5 never exceeded 1 per cent For operation 4 the error was, of course, considerably greater, reaching as much as 15 per cent in one test for a steep curve

---

6 *Report on the Further Tabulation of Bessel and other Functions.* See Reports, p 39

Joint Discussion with Section M on the Connection between Agriculture and Meteorology —See p 738

TUESDAY, SEPTEMBER 10

Discussion on Series in Spectra
Opened by Dr J W. NICHOLSON, *M A*

Dr Nicholson gave a general account of the work which has been done in the representation of spectra by formulæ, with a detailed account of Rydberg's work on hydrogen, in which the principal series is deduced from a knowledge of the nebular series, given by Balmer's formula

$$\lambda = \lambda_0 \frac{n^2}{n^2 - 4}$$

and the sharp series

$$\lambda = \lambda_0 \frac{(n + \frac{1}{2})^2}{(n + \frac{1}{2})^2 - 4}$$

discovered by Pickering in certain stars

This was followed by a review of the attempts made to obtain these formulæ from model atoms, with a more detailed account of that of Ritz, whose formula has been modified with such success by Hicks It was concluded that the theory given by Ritz cannot actually represent the actual phenomena, and that Hicks' modification is difficult to interpret physically—a remark which applies also to that of Whittaker

A modern theory must apparently build up the atom from electrons and positive electricity—the latter, from work on radioactivity alone, being densely concentrated at the centre of the atom The electrons must be arranged in rings to avoid excessive radiation (Schott), and the atom is Saturnian The necessary permanence of structure can be secured by allowing expansion of electrons, as Schott supposes, or by a quantum theory, which is preferable

It has been shown that it is possible to explain the coronal and nebular spectra by simple ring-systems, with a quantum theory which implies a definite

change of energy only when an electron enters or leaves the atom Such systems constitute unstable elements of a simpler nature than those on the earth The spectra of such elements do not exhibit the usual series, but a series in which the cube roots of the wave-lengths differ by a constant amount This is in accordance with a radiation of energy in discrete amounts proportional to the frequency

The main difficulty in supposing that the dynamical vibrations of systems of electrons can give spectrum series such as Balmer's lies in the fact that the *square* of the frequency is then a rational function of integers, and not the frequency itself This difficulty is absent from the model of Ritz But it is more probable that Lord Rayleigh's suggestion is correct--that the origin of spectral series is kinematical rather than dynamical

A process was sketched by which a series of lines

$$\lambda = \lambda_0 \frac{n^2}{n^2 - a^2}$$

(a = constant) can be obtained for an atom with two rings of electrons by simple kinematical principles If the outer ring contains only one electron, the lines are doublets Hydrogen is perhaps built up in this way, which is in accord with its unit valency The infinite number of lines is due to the infinite number of degrees of freedom of the ether

---

The following Report and Papers were then read —

1 *Report of the Seismological Committee* —See Reports, p 69

2 *Some Notes on Periodograms* By Professor H H TURNER, *F R S.*

An analysis of the catalogue of large earthquakes indicates a periodicity of nearly fifteen months, which is dealt with in the report of the Seismological Committee Further examination suggests that some of the deviations there shown may be due to the existence of neighbouring periodicities which have not yet been fully examined But attention has been concentrated on the existence of pairs of periodicities, or groups of periodicities (analogous to double lines or groups of lines in a spectrum), by related work on the variations of level and azimuth of the Greenwich and Cape transit circles As an example the following results may be tabulated for periods near twelve months, hitherto perhaps obscured by the well known twelve-month period —

Azimuthal Variations near Twelve Months

Period in Months	Coefficient		Phase		
	Greenwich	Cape	G	C	G − C
11 76	0″ 20	2″ 6	294°	106°	188°
11 60	0″ 19	1″ 0	315°	145°	170°
12 40	0″ 16	1″·0	215°	48°	167°

The 11 76 month period occurs in the Greenwich rainfall (eighty years' observations) Such independent confirmation seems to render the real existence of these close periodicities very probable The examination of such points is being continued

---

3 *The Periodogram and the Method of Correlation* *By* J I CRAIG, *F R S E*

1. At Portsmouth last year, Professor Turner gave an explanation of Professor Schuster's method of analysing a series of figures for suspected periodicities, and applied the method to examine seismic records for possible periods. Professor Karl

Pearson has investigated the now well-known method of correlation to detect hidden connections between sets of variables. It is the object of this note to show that these methods are connected, and to suggest a slight modification in Professor Schuster's measure of the intensity of the periodic movement.

2. Suppose we have a series of n numbers and are looking for a periodic repetition in groups of p. Then *qua* periodic the numbers will be comparable with the periodic series obtained by giving all values from 1 to n to k in $a \cos k\alpha + b \sin k\alpha$, where $\alpha = 2\pi/p$. This suggests that we may obtain the values of a and b by correlating the given series $x_1, x_2 \ldots x_n$, with the two series S $\cos k\alpha$ and S $\sin k\alpha$.

For this purpose we require the standard deviations of the three series. That of the given series may be found in the usual way: let it be s.

Since $\sum\limits_{k=1}^{p} \begin{matrix}\cos\\ \sin\end{matrix}\, k\alpha = 0$, and for the present we shall assume that n is a multiple of p, the mean value of $\begin{matrix}\cos\\ \sin\end{matrix}\, k\alpha$ is zero, and the squared standard deviations are $y^2 = \frac{1}{n}\sum\limits_{1}^{p} \cos^2 k\alpha = \frac{1}{2} = \frac{1}{n}\sum\limits_{1}^{p} \sin^2 k\alpha = \sigma^2$. Or $\sigma = y = 1/\sqrt{2}$.

3. Since the sum of the products $\sum\limits_{1}^{p} \cos k\alpha \sin k\alpha = 0$, there is no correlation between the two trigonometrical series.

We now require the mean products of the deviations of the given and trigonometrical series, term by term, for the evaluation of the coefficient of correlation. These are $\frac{1}{n}\sum\limits_{1}^{n}(x_k - \bar{x}) \cos k\alpha$ and $\frac{1}{n}\sum\limits_{1}^{n}(x_k - \bar{x}) \sin k\alpha$, where $\bar{x}$ is the mean of the given series, and $x_k - \bar{x}$ is the deviation. Since, however, $\Sigma\bar{x} \cos k\alpha = \bar{x}\Sigma \cos k\alpha = 0 = \Sigma\bar{x} \sin k\alpha$, we may operate on the original series in place of the deviations of its terms.

Professor Schuster writes $A_p = \sum\limits_{1}^{n} x_k \cos k\alpha$, $B_p = \sum\limits_{1}^{n} x_k \sin k\alpha$ and uses $I = A_p^2 + B_p^2$ as a measure of the intensity of the periodic movement. In Pearson's method, the coefficients of correlation are $r = A_p/nys = A_p\sqrt{2}/ns$ and $r' = B_p\sqrt{2}/ns$, and the coefficient of total correlation is R, where

$$R = r^2 + r'^2 = 2(A_p^2 + B_p^2)/n^2 s^2 = 2I/n^2 s^2 .$$

R or R² is proposed as a modified measure of the precision of the periodicity. It differs from Schuster's criterion in having $n^2 s^2/2$ as a divisor of his I, and from the criterion adopted by Turner (*op. cit.*) in replacing his Σx by $n\Sigma(x - \bar{x})^2$. It has the advantage of being more absolute than either of the other two. Personally I prefer R² to R, as giving a less exaggerated idea of the closeness of fit.

The equation of regression is

$$x - \bar{x} = (rs/y) \cos k\alpha + (r's/\sigma) \sin k\alpha = \frac{2}{n} A_p \cos k\alpha + \frac{2}{n} B_p \sin k\alpha,$$

the well-known result of harmonic analysis.

4. Applying these results to the first and fifth groups given by Professor Turner last year, we find

	First Group	Fifth Group.
Mean	4 77	27 63
Standard deviation	2 76	8 53
r	−0 205	+0 213
r'	−0·279	+0 128
R	0 34	0 25
Probable error of R	±0 10	±0 11

Compared with its probable error, R is not so large in either case as to prove periodicity beyond a doubt.

5. So far only integral periods have been considered. When non-integral periods are suspected they may be approximately determined by considering consecutive values of R and interpolating, by a quadratic formula, to obtain that value of the period for which R is a maximum. This process would fail if there were two periods in the interval between two consecutive integral periods. Then it would be necessary to calculate R for periods of the form $p, p + \frac{1}{2}, p + 1$, or $p, p + \frac{1}{3}, p + \frac{2}{3}, p + 1$, &c., as shown by Professor Turner (*op. cit.* p. 335).

6. One frequently sees claims put forward for periodicities of various kinds in meteorology and cognate sciences, just as one sees claims for proportionality; but just as in the later case it is now obligatory to give some numerical measure of the precision of the proportionality, either by the error of mean square, or by the co-efficient of correlation, so it is not too much to say that it is obligatory on claimants for periodicity to give a measure of the precision of their claim Otherwise, by Lord Kelvin's dictum, their claim cannot rank as work of scientific value.

Department of General Physics

The following Papers were read —

1. *The Pressure Effect as a Means for the Resolution of a Spectrum into Series of Lines* *By* W Geoffrey Duffield, *D Sc*

Photographs were offered showing the different behaviour of spectral lines under pressure, which facilitates their grouping Not only are the ordinary series lines affected in this way, but also non series lines Grouping is rendered possible by the following features which are emphasised under pressure —

(1) The general appearance of the line—sharp or nebulous
(2) Its relative change of intensity under pressure
(3) The nature of its broadening, which may be symmetrical or asymmetrical, with different degrees of asymmetry
(4) The nature of its reversal, which may be symmetrical or asymmetrical with regard to the line upon which it is superposed
(5) The direction and amount of the displacement

It is sometimes possible to subdivide a general group into triplets by means of the appearance of the spectrum under pressure No 5 affords a means for obtaining the numerical relations between the different groups

There is some evidence for believing that the vibrating systems which produce the different groups are different, the various systems showing different variabilities in the same environment

2 *Photographs of the Arc Spectrum of Nickel under Pressure* *By* W Geoffrey Duffield, *D Sc*

Photographs of the arc spectrum of nickel have been taken when the pressure of the air surrounding the poles of the metal was varied from 1 to 10 atmospheres throughout a large range of the spectrum For a portion of the spectrum 201 atmospheres have been reached

The photographs illustrate the broadening, displacement, and reversal of the lines, and afford some means of resolving the spectrum into different groups of lines

In general the effects resemble those obtained with the iron arc under pressure

3 *On the Calculation of the Fields of Telescopic Object Glasses* *By* Professor R A Sampson, *F R S*

4 *The Optical Rotatory Power of Quartz* *By* T Martin Lowry, *D Sc* , *F C S*

The chief difficulties in measuring the optical rotation of light in quartz are (1) to secure crystals of quartz which are entirely free from optical faults, and (2) to produce light of sufficient purity to give a clean extinction when reading a rotation of several thousand degrees and of sufficient intensity to be read with a small half-shadow angle The best tests of the optical purity of quartz are (1) to illuminate the quartz plate or rod with monochromatic green

mercury light between Nicols set to extinction, and then to examine it by means of a telescope focussed on the interior of the crystal, (2) to read its optical rotatory power with mercury-green light, using both a positive and a negative half-shadow angle Rods cut from a flawless crystal-plate of lævo-quartz weighing about two kilos gave an optical rotation of 25°·5371 per mm at 20° C for $\lambda = 5461$ on a total length of 226 mm, rods cut from a plate of dextro-quartz, containing local faults, gave the figure 25° 5361 per mm on a total length of 181 mm Observations taken with light of twenty-four different wave-lengths showed errors of reading amounting on the average to only six parts per million, the errors from all sources were probably not greater than 0° 001 to 0° 002 per mm, as the average deviation from values calculated from a formula was only 0° 0015 per mm

---

5 *Calibration of a Wave-length Spectroscope in the Infra-red Region of the Spectrum* By T Martin Lowry, *D Sc*, *F C S*

A wave-length spectroscope, provided with a slit, thermopile and galvanometer instead of an eyepiece, was calibrated (*a*) by plotting the maxima and minima of the light transmitted from a Nernst lamp through a lightly silvered etalon, (*b*) by locating the principal infra red lines in the spectrum of the mercury arc The line at λ 10,140 coincided with the fourteenth maximum of the etalon, and was used as the principal fixed point in the calibration The calibration was probably correct within $\frac{1}{200}$ to $\frac{1}{100}$ of a drum revolution from λ 8,000 to λ 17,000, corresponding to a possible error of 20 to 50 Angstrom units From λ 17,000 to λ 20,000 the calibration was less exact and the errors may have amounted to 100 units

---

6 *Registration and Analysis of Sound Vibrations* By Professor D C Miller

---

Department of Meteorology

The following Papers and Reports were read —

1 *Recent Investigations of the Temperature of Fresh-water Lakes* By E M Wedderburn, *F R S E*

At the Dublin meeting of the Association in 1908 the author communicated a paper describing certain oscillations of temperature in Lochs Ness and Garry, to which the name of Temperature Seiche was given He has since been concerned in observations in the Madusee, Pomerania, and Loch Earn, Perthshire, undertaken in order to further establish the oscillatory nature of the changes observed The Madusee observations were conducted jointly with Professor Halbfass, Jena, who did not admit that the temperature seiche was likely to be found save in deep lakes situated in deep glens, such as Loch Ness and Loch Garry But a temperature seiche was found in the Madusee, which is situated in a flat country The shores everywhere are of a shelving nature, and therefore the conditions are quite different from what is usually found in Scottish lochs

The observations in Loch Earn were on a more ambitious scale, for two-hourly (sometimes hourly) observations were made at five points along the loch for about four weeks A record was kept of meteorological data, and in particular a pressure-tube anemograph was used for recording the strength of the wind In this way it was frequently possible to explain variations in temperature by reference to meteorological conditions During part of the period of observation a good example of a temperature seiche was observed, and it was possible to distinguish uninodal and binodal periods The observations at each end of the loch showed clearly the opposition in phase of the uninodal seiche and

observations at the centre showed no unimodal period, but did show the binodal period

As the sides of the Madusee were so shelving it was not possible to apply a mathematical theory to the calculation of the period of the oscillations which involved a rectangular approximation to the shape of the lake basin The discontinuity of temperature between the surface and bottom water was, however, very abrupt, and a mathematical theory was evolved on the assumption of a sudden discontinuity of temperature at a given depth, but applicable to a basin of variable depth and breadth This theory gave excellent results when applied to the computation of the period for the Madusee, and laboratory experiments with troughs of varying shapes gave conformable results In Loch Earn, however, the discontinuity was not very abrupt, and the theory did not give such good results It was further extended to the cases of oscillations in a liquid of gradually varying density—the observed period of the unimodal temperature seiche for Loch Earn was 15 2 hours, and the period calculated according to the author's theory was 15 hours The following are the assumptions involved in the theory (1) It was assumed that in the oscillations (*a*) the motion of water particles was irrotational, (*b*) the amplitude was small, and (*c*) that there was no transverse motion of water particles (2) A condition was imposed that at a certain depth there was no horizontal motion—which necessitated that above and below that depth the horizontal motion was in opposite directions, and that there was slipping at the boundary There is a certain amount of arbitrariness in fixing the depth at which to assume this boundary, but it seems a reasonable supposition to fix the depth where the density gradient is greatest With these assumptions the theory is found to depend on the differential equation

$$\frac{\partial^2 P}{\partial v^2} + \frac{n^2 P}{g\sigma(v)} = 0$$

where u is function depending on the contour of the lake and the horizontal displacement of water particles, v is a function depending on the contour of the lake and the depth chosen for the boundary; $\sigma(v)$ a function depending on v and the distribution of density, $u = \Sigma\, P \sin n\,(t-\tau)$ where P is a function of v alone, τ is constant, and the value of n depends on the circumstances of each case

This equation is of exactly the same form as the equation arrived at by Professor Chrystal in the case of the ordinary seiche, and therefore the modes of computation and approximation elaborated by him are available The similarity between the equations for the ordinary seiche and the temperature seiche also shows how close is the analogy between the two modes of oscillation Given the period of the ordinary seiche and the distribution of density it is possible to give a close approximation to the period of the temperature seiche

2 *Report on Magnetic Observations at Falmouth Observatory*

See Reports, p 103

3 *On the Velocity and Direction of the Wind above Ground Level*

By Miss Margaret White, *M Sc*

Conclusions are based on the results of kite and balloon ascents obtained daily at Glossop Moor, Derbyshire, over the two years 1908-1910, and comprising some thousand ascents

Wind velocities are measured in metres per second, heights in metres, and gradients of wind velocity in metres per second per 100 metres, an increase of wind velocity with height being accounted a positive gradient

Increase of Wind Velocity with Height —Near the ground level the wind velocity increases very rapidly with height, the gradient decreases continuously to about 1,000 m , above which it is more or less constant, at about a tenth its value over the first level, ground to 500 m

The average wind velocities for the two years are.—

Height	Ground 335m	500	750	1000	1250	1500	1750	2000
Velocity m.p.s.	5.0	8.5	11.0	11.8	12.7	12.9	13.5	13.6

Seasonal Variation.—The wind velocity at all levels is slightly greater in winter than in summer, the average velocities for the two seasons for successive 250 m. above m.s.l. being as follows.—

——	Ground 335m	500	750	1000	1250	1500	1750	2000
Winter . . .	5.2	9.0	11.6	12.5	12.8	13.6	13.9	13.9
Summer . .	4.7	8.1	10.4	11.2	12.0	12.4	13.3	13.3

Average monthly wind velocities have been calculated, but neither maximum nor minimum value of the velocity is sharply defined at any particular month.

Variation of Wind Velocity with High and Low Barometer.—Both in winter and summer the ground wind velocity is greater and the increase with height more rapid under cyclonic than anticyclonic conditions. The average wind velocities for barometer above and below 760 mm. respectively are as follows.—

Barometer	Ground 335m	500	750	1000	1250	1500	1750	2000
Above 760 . .	4.3	7.7	9.9	10.7	11.6	11.9	12.8	12.8
Below 760 .	5.7	9.6	12.3	13.1	13.9	14.2	14.5	14.6

Variation of Wind Velocity with Direction of Ground Wind.—For all values of the ground wind velocity the rate of increase for S.E., E. and N.E. winds is much less rapid than for winds from other directions. For example, the average velocities under the two conditions are, for ground winds between 4 and 6 m.p.s.

Direction of Wind	Ground	500	750	1000	1250	1500	1750	2000
S.E., E., N.E.	4.8	8.8	11.6	12.4	12.4	12.3	12.8	12.3
N., N.W., W., S.W., S. .	4.8	9.2	12.3	13.5	14.1	14.9	15.3	15.8

Variation of the Upper Wind with Ground Wind Velocity.—The increase of wind velocity with height appears to be additive, and does not vary with the velocity at the ground level.

Variation of Wind Velocity with Time Rate of Change of Barometer.—The wind velocity at all heights is great when the barometer is rising or falling quickly, but apparently does not depend on the sign of the change. The effect is more marked in winter than in summer.

Rotation of Wind Direction with Height.—Generally speaking, the wind rotates in a clockwise direction with height—*i.e.*, a S. wind becomes more westerly, a W. wind more northerly, at the higher levels. This rotation is a maximum for S. and a minimum for N. winds, the average total rotation measured clockwise in degrees being at 2,000 m. as follows. For N. ground winds, 2°.6, E. winds 14°.5, S. winds 28°.1, W. winds 12°.8.

Tables were included giving the variation of wind rotation with direction, season, and height above m.s.l.

Agreement of Observed Wind Velocity and Direction with the 'Gradient Wind' **as calculated from the formula $G = 2\omega\sigma V \sin\phi$ and corrected for curvature of the isobars, the direction being taken as parallel to the isobars.**

Calculations of the gradient wind at 7 A M and 6 P M, as given by the distribution of the isobars on the M O charts, were made, and compared with the winds recorded in ascents within two hours of these times

The ground wind velocity is generally below that given by the formula, but becomes equal to it at about 650 m

The height at which the observed wind reaches the theoretical velocity varies considerably with the direction of the wind, and with the season

At the ground the observed wind has a component directed towards the low pressure, the angle to the theoretical averaging 22° This decreases with height until at 2,500 m the average angle is only 8°

Diagrams and tables substantiating the above conclusions appeared in detail in the paper, which included also a number of subsidiary questions

Note —1 metre per second = 2 24 miles per hour

4 *Report on the Investigation of the Upper Atmosphere*

See Reports, p 105

5 *On the Temperature of the Upper Atmosphere*

By Miss Margaret White, *M Sc*

Conclusions are based on the results of kite and captive balloon ascents, made daily at Glossop Moor, Derbyshire, during 1908 and 1909, and comprising some thousand ascents

Temperatures are measured in degrees Centigrade, heights in metres above m s l, and temperature gradients in degrees C per 100 metres, a decrease of temperature with height being reckoned a positive gradient

Variation of Temperature with Height —The average temperatures at successive 250 m above m s l were as below —

—	Ground 335m	500	750	1000	1250	1500	1750	2000
Temperature °C	9 0	7 6	5 9	4 2	3 0	2 0	1 2	0 4

These figures agree closely with those for other English stations

The average temperature gradients, calculated from the individual gradients, are —

—	Ground to 500	500 to 750	750 to 1000	1000 to 1250	1250 to 1500	1500 to 1750	1750 to 2000
Temperature Gradient	0 85	0 75	0 62	0 51	0 48	0 42	0 43

Temperatures and Temperature Gradients under Cyclonic and Anticyclonic Conditions —At all levels, day or night, summer or winter, the temperature is lower, and the rate of fall of temperature with height more rapid, under cyclonic than anticyclonic conditions The average values of temperature and temperature gradient are as follows —

Average Temperatures

—	Ground	500	750	1000	1250	1500	1750	2000
Summer, A .	13 4	11 4	9 6	8 1	6 8	5 8	5 1	3 9
,, C	11 5	9 8	7 6	5 7	4 1	3 0	1 8	1 4
Winter, A	3 8	2 8	1 5	0 2	−0 5	−1 8	−2 5	−3 3
,, C	3 9	2 7	1 1	−0 6	−2 3	−3 6	−4 4	−5 7

Average Temperature Gradients

—	Ground to 500	500 to 750	750 to 1000	1000 to 1250	1250 to 1500	1500 to 1750	1750 to 2000
Summer, A .	0.98	0.82	0.56	0.41	0.43	0.37	0.41
„ C	1.03	0.87	0.72	0.66	0.56	0.50	0.45
Winter, A	0.60	0.53	0.55	0.41	0·36	0.40	0.38
„ C	0.73	0.69	0.68	0.66	0.61	0.61	0.52

Winter and Summer.—The above figures show that near the ground, both under anticyclonic and cyclonic conditions, the temperature gradient is larger in summer than in winter.

Day and Night.—During the summer of 1909 ascents were made throughout the twenty-four hours. The temperature gradient near the ground is larger in the daytime than at night.

Average Temperature Gradients

—	Ground to 500	500 to 750	750 to 1000	1000 to 1250	1250 to 1500	1500 to 1750	1750 to 2000
Day .	0.93	0.90	0.66	0.50	0.49	0.47	0.45
Night	0.50	0.62	0.60	0.48	0.41	0.48	0.51

Diurnal Variation.—The temperature gradient near the ground shows a well-defined maximum at about 1 p.m. or 2 p.m. which is not appreciable above 1,250 m., *e.g.*, the temperature gradients in summer are as follows:—

Height	7 a.m.	9 a.m.	11 a.m.	1 p.m.	3 p.m.	5 p.m.	7 p.m.	9 p.m.
335 to 500	0.90	0.88	0.99	1.00	1.14	0.85	0.56	0.69
500 to 750	0.64	0.78	0.83	0.97	0.95	0.86	0.67	0.59

Variation with Wind Direction.—The temperature gradient to 1,000 or 1,250 m. is small for S., S.E., E. winds, and more or less constant, but larger, for the other directions. The average gradients for S., S.E., E. winds are compared below with those for other directions:—

—	Ground to 500	500 to 750	750 to 1000	1000 to 1250	1250 to 1500	1500 to 1750	1750 to 2000
Other directions	0.94	0.86	0.69	0.52	0.46	0.36	0.39
S., S.E., E.	0.61	0.53	0.47	0.48	0.52	0.50	0.47

Variation with Wind Velocity.—Near the ground the temperature gradient is high with high wind velocities, but the effect is not large.

Variation with Temperature at Ground.—The temperature gradient in the lower layers is higher the higher the ground temperature.

Height	Temperature Gradient, °C					
	18°	14°	10°	6°	2°	−2°
Ground to 500 . .	1.13	0.97	0.86	0.67	0.57	0.47
500 to 750 .	0.94	0.83	0.79	0.69	0.57	0 7

Temperature Inversions and Zero Gradients may be taken to represent simply extreme cases of small gradients. They generally occur, as the foregoing would

lead one to predict, with a high barometer and S E wind; near the ground they are more frequent in winter and at night

The paper included in detail tables and diagrams illustrating and verifying the conclusions given, and a shorter discussion of several minor considerations

WEDNESDAY, SEPTEMBER 11

The following Papers and Reports were read —

1 *The Current-Potential Curves of the Oscillating Spark* *By* S R MILNER, *D Sc*

Two induction-coils connected in series were actuated by the same mercury break, one of these charged a Leyden jar battery and produced the spark, the other simultaneously discharged through a vacuum tube giving cathode rays which served as an indicator of the curves The rays were deviated in two directions at right angles by the magnetic field of the spark current, and by the electric field of the spark p d, and photographs of the resulting curves due to single sparks were presented to the Section The oscillating discharge possesses a p d (35 volts) characteristic of the arc during the main part of each oscillation, but a glow discharge with a p d of about 300 volts occurs for a short period when the current is changing sign The curves confirm and extend Roschansky's observations on the spark

A distinguishing feature of the oscillating spark is probably the comparatively low temperature of the instantaneous anode which exists in it This view explains not only the occurrence of the glow discharge at the instant when the current is changing sign, but also the fact that the metal vapour streamers which are seen when the image of the spark is examined in a rotating mirror are invariably associated with the instantaneous cathode The low temperature of the anode was ascribed to the effect of the different penetrating powers of the corpuscles and the positive ions which bombard the anode and the cathode respectively The positive ions have a small penetrating power and expend their energy in raising the temperature of a layer of the cathode surface only a few molecules thick, the corpuscles with their larger penetrating power penetrate the anode to a greater extent, and consequently produce a smaller rise of temperature of the surface layer

2 *A Case of Anomalous Conduction in a Solid Dielectric* *By* W F G SWANN, *D Sc*

The conductivity of paraffin wax was investigated for potential gradients of the order of 100,000 volts per centimetre by a new method, and was found to increase with the field

A plate C was fixed between, and parallel to, two outer plates A and B, which were provided with guard rings C was placed nearer to A than to B The space between the plates was filled with paraffin wax, C being completely immersed in the wax A and B being earthed, C was charged through a fine hole in the wax, the hole being afterwards sealed up The plates A and B were released from earth at intervals, and their rates of alteration of potential were noted By plotting this quantity against the time, two curves were obtained, one for A and the other for B The corresponding ordinates for the two curves were found to be equal but of opposite sign Theory shows that if Ohm's law is obeyed neither A nor B should alter in potential as the electricity leaves C, the rise of potential of A, for example, due to the passage of electricity from C to A, being just counterbalanced by the fall due to the transference of electricity from C to B. If the conductivity decreases with the field we should find that if C is positively charged, B rises and A falls If the conductivity increases with the field we should find, as was actually found, that A rises and B falls in potential The paper concluded with a discussion of the theory of dielectric conduction

3. *Note on Measurements of the Specific Heats of Gases.* *By* W. F. G. Swann, *D.Sc.*

---

4. *On the Series Lines in the Arc Spectrum of Mercury, and on their Resolution by an Echelon Grating.* *By* Professor J. C. McLennan.

---

5. *Report of the Committee on Electrical Standards.*
See Reports, p. 109.

---

6. *Report of the Committee to aid in Establishing a Solar Observatory in Australia.*—See Reports, p. 113.

---

7. *Report on the International Tables of Physical and Chemical Constants.*

8. *Photographs of a Deposit upon the Poles of an Iron Arc burning in Air.* *By* Dr. W. G. Duffield *and* G. E. Collis.

Soon after an arc is struck between iron poles a fine deposit appears upon both poles, but more abundantly upon the upper one. This increases in quantity as time goes on, and may extend to the whole length of the upper pole. In the immediate neighbourhood of the arc the deposit assumes forms which may be described as resembling a tree, because a large mass may be connected by one short trunk to the pole, or it may resemble a fern leaf, or it may be best described as feathery.

With the currents used—5 to 8 ampères—little difference was noticed when the polarity was reversed. In the photographs shown the negative was usually the top pole.

The deposit formed in greatest abundance upon the edge of the upper pole, and appears to be an oxide of iron. It is magnetic, but this is possibly due to the admixture of small particles of iron which had been shot off from the pole. The growths vary from a millimetre to a centimetre in length; they increase in size by the condensation of metallic vapour or the vapour of an oxide of iron. Occasionally, when the arc has been stopped, fine filaments have been observed bridging the poles; in places they are as fine as one-hundredth millimetre in diameter.

9. *On a New Method of Determining Vapour Densities.* *By* Dr. G. E. Gibson.

All methods of vapour density determination hitherto in use, in which quartz or glass manometers are employed, suffer from the disadvantage that the highest temperature attainable is about 750° C.

Above this temperature quartz loses its elastic properties, so that the manometer becomes useless for accurate measurements.

It is, however, possible to overcome this difficulty whenever the vapour pressure of the substance under investigation is considerable below 750° C.

If we heat the bulb—volume V—which contains the main bulk of the vapour in one furnace whose temperature, T, may be varied at will, and the manometer—volume v—in a separate furnace at a constant temperature, t—less than 750° C.—we can calculate the vapour density Δ, relative to hydrogen, at the temperature T by the formula

$$\Delta = \frac{m}{\mu}\frac{\mathrm{RT}}{pv} - \frac{v\mathrm{T}}{\mathrm{V}t}\delta,$$

where R is the gas constant, m is the total weight of substance, μ is the

molecular weight of hydrogen (2 016), p is the measured pressure and δ is the vapour density of the substance at pressure p and temperature t

The quartz manometers hitherto in use are voluminous and difficult to manipulate The author has devised a quartz manometer which is exceedingly compact and easy to manipulate.

It consists of a bulb of less than 1 c c capacity blown on a quartz tube 3 mm in diameter and flattened at one end so as to form a flexible membrane one-tenth mm thick The interior of this membrane is filled with the vapour under investigation, while the exterior is enclosed in a quartz chamber which communicates with a mercury manometer

A distortion of the membrane caused by a difference in pressure between the interior and the exterior causes a small quartz plate, which is polished so as to act as a mirror, to undergo a rotation about an axis in the plane of the polished surface

The excursions of the image of an illuminated slit reflected from this mirror indicate the movements of the membrane

The zero point corresponding to the undistorted position of the membrane is indicated by a second image of the slit reflected from a fixed mirror

The whole manometer, with mirrors, connecting mechanism, &c , is enclosed in a quartz tube 8 cm long and 1 cm diameter

The author has made determinations by this method up to 1250° C The method is specially adapted to the investigation of substances which dissociate at high temperatures

Section B.—CHEMISTRY.

President of the Section:
Professor A. Senier, Ph.D., M.D., D.Sc.

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

Part I.

The nature and method of Chemistry.

Perhaps there is no intellectual occupation which demands more of the faculty of imagination than the pursuit of chemistry, and perhaps also there is none which responds more generously to the yearnings of the inquirer. It is surely no commonplace occurrence that in experimental laboratories day by day the mysterious recesses of Nature are disclosed and facts previously quite unknown are brought to light. The late Sir Michael Foster, in his presidential address at the Dover meeting, said: 'Nature is ever making signs to us, she is ever whispering the beginnings of her secrets.' The facts disclosed may have general importance, and necessitate at once changes in the general body of theory, and happily, also, they may at once find useful application in the hands of the technologist. Recent examples are the discoveries in radio activity, which have found an important place as an aid to medical and surgical diagnosis and as a method of treatment, and have also led to the necessity of our revising one of the fundamental doctrines of the theory of chemistry—the indivisibility of atoms. But the facts disclosed may not be general or even seem important, they may appear isolated and to have no appreciable bearing on theory or practice—our journals are crowded with such—but he would be a bold man who would venture to predict that the future will not find use for them in both respects. To be the recipient of the confidences of Nature, to realise in all their virgin freshness new facts recognised as positive additions to knowledge, is certainly a great and wonderful privilege, one capable of inspiring enthusiasm as few other things can.

While the method of discovery in chemistry may be described, generally, as inductive, still all the modes of inference which have come down to us from Aristotle, analogical, inductive and deductive, are freely made use of. A hypothesis is framed which is then tested, directly or indirectly, by observation and experiment. All the skill, all the resource the inquirer can command, is brought into his service, his work must be accurate, and with unqualified devotion to truth he abides by the result, and the hypothesis is established, and becomes part of the theory of science, or is rejected or modified. In framing or modifying hypotheses imagination is indispensable. It may be that the power of imagination is necessarily limited by what is previously in experience—that imagination cannot transcend experience, but it does not follow, therefore, that it cannot construct hypotheses capable of leading research. I take it that what imagination actually does is—it rearranges experience and puts it into new relations, and with each successive discovery it gains in material for this process. In this respect the framing of a hypothesis is like experimenting, wherein the operator brings matter and energy already existing in Nature into

new relations, new circumstances, with the object of getting new results. The stronger the imaginative power the greater must be the chance of success The 'Times,' in a recent leading article on Science and Imagination, says. 'It has often been said that the great scientific discoverers see a new truth before they prove it, and the process of proof is only a demonstration of the truth to others and a confirmation of it to their own reason' While never forgetting the essentially tentative nature of a hypothesis, still, until it has been tested and found wanting, there should be some confidence or faith in its truthfulness; for nothing but a belief in its eventual success can serve to sustain an inquirer's ardour when, as so often happens, he is met by difficulties well-nigh insuperable In a well-known passage Faraday says 'The world little knows how many of the thoughts and theories which have passed through the mind of a scientific investigator have been crushed in silence and secrecy by his own severe criticism and adverse examination, that in the most successful instances not a tenth of the suggestions, the hopes, the wishes, the preliminary conclusions have been realised.'

But a hypothesis to be useful, to be admitted as a candidate for rank as a scientific theory, must be capable of immediate, or at least of possible, verification Many years ago, in the old Berlin laboratory in the Georgenstrasse, when our imaginations were wont, as sometimes happened, to soar too far above the working benches, our great leader used to say 'I will listen readily to any suggested hypothesis, but on one condition—that you show me a method by which it can be tested' As a rule, I confess we had to return to the workaday world, to our bench experiments No one felt the importance of the careful and correct employment of hypotheses more than Liebig In his Faraday lecture Hofmann says of Liebig 'If he finds his speculation to be in contradiction with recognised facts, he endeavours to set these facts aside by new experiments, and failing to do so he drops the speculation' Again, he gives an illustration of how on one occasion, not being able to divest himself of a hypothesis, he missed the discovery of the element bromine While at Kreuznach he made an investigation of the mother-liquor of the well-known salt, and obtained a considerable quantity of a heavy red liquid which he believed to be a chloride of iodine He found the properties to be different in many respects from chloride of iodine, still, he was able to satisfy all his doubts, and he put the liquid aside Some months later he received Balard's paper announcing the discovery of bromine, which he recognised at once as the red liquid which he had previously prepared and studied Thus, though imagination is indispensable to a chemist, and though I think chemists should be, and let us hope are, poets, or at least possess the poetic temperament, still, little can be achieved without a thorough laboratory training, and he who discovers an improved experimental method or a new differentiating reaction is as surely contributing to the advancement of science as he who creates in his imagination the most beautiful and promising hypothesis

It may never be possible to trace in civilisation's early records the exact period and place of the origin and beginnings of our science, but the historical student has been led, it appears to me, by a sure instinct to search for this in such lands of imaginative story as ancient Egypt and Arabia For is there anything more fittingly comparable with the marvellous experiences of a chemical laboratory than the wonderful and fascinating stories that have come down to us in 'The Arabian Nights'? Those monuments of poetical building of which Burton, in the introduction to his great translation, says that in times of official exile in less-favoured lands, in the wilds of Africa and America, he was lifted in imagination by the jinn out of his dull surroundings, and was borne off by him to his beloved Arabia, where under diaphanous skies he would see again 'the evening star hanging like a golden lamp from the pure front of the western firmament, the after-glow transfiguring and transforming as by magic the gazelle-brown and tawny-clay tints and the homely and rugged features of the scene into a fairyland lit with a light which never shines on other soils or seas Then would appear, &c' I cannot help thinking that the study of such books as this, the habit of exercising the imagination by reconstructing the scenes of beauty and enchantment which they describe, might do much to strengthen and sharpen the imaginative faculty, and greatly increase its efficiency

as an indispensable tool in the hands of the pioneer who seeks to extend the boundaries of knowledge The 'Times,' in the leading article already quoted, says that, as with a Shakespeare, 'it is the same with imaginative discoverers in science But the faculty is not merely a fairy gift that can be exercised without pains As the sense of right is trained by right action, so the sense of truth is trained by right thinking and by all the labour which it involves That is as true of the artist as of the man of science, and one of the greatest achievements of science has been to prove this fact and so to justify the imagination and distinguish it from fancy'

Again, let it not be forgotten that chemistry in its highest sense—that is, in its most general and useful sense—is purely a world of the imagination, is purely conceptual And in addition to this, moreover, it is based, like all science, on the underlying assumption of the uniformity of Nature, an assumption incapable of proof If we think of the science as a body of abstract general theory, and exclude for the moment from our purview its innumerable practical applications, and also all special individual facts not yet known to be related to general theory, then what remains are the more or less general facts or laws These it is which give the power of prediction in newly arising cases of a similar character, the power of foresight by which the claim of chemistry to its position as a science is justified Chemistry, as such is a complicated ideal structure of the imagination, a gigantic fairy palace, and, be it noted, can only continue to exist so long as there are minds capable of reproducing it Think of all the speculation—and speculation too of the highest utility when translated into concrete applications—about the internal structure of molecules I venture to say that the most magnificent creations of the world's greatest architects are not more elaborate or more beautiful or more fairylike than the chemist's conception of intramolecular structure and the magical transformations of which molecules are capable, and yet no one has had direct sensuous experience of any molecule or atom, or possibly ever will It is well from time to time to recall these truths and realise where we are But although the conceptual nature of science is unquestionable, it certainly contains truth in some form as tested by deductive concrete realisation, by correctness of prediction, and during the last century or two has undoubtedly given to man a mastery over Nature never before dreamt of

A brief historical retrospect.

The foundations of chemistry, as we now know it, were laid under the influence, the guidance, of three great theories first, the theory of the alchemists of the transmutation of metals by means of the philosopher's stone, second, the theory of phlogiston, connected so much with the names of Becher and Stahl, which held sway for some two centuries, third, the theory of combustion, the quantitative period of chemistry, inaugurated by the great Scottish chemist Black by his introduction of the balance How this led to a veritable renascence of chemistry in the hands of Lavoisier and the other giants of that stirring period—the close of the eighteenth and commencement of the nineteenth centuries—is well known Looking back at the warfare which was waged about these older theories, for and against them, one realises now that there were elements of truth on both sides, for have we not in the work of Sir William Ramsay and others the revival of transmutation, and does not the essential truth of phlogiston survive in the modern doctrine of heat? In one of Dr Johnson's letters to Boswell there is a curious reference to transmutation He says that a learned Russian had at last succeeded, but, fearing the consequences to society, he had died without revealing the secret

After the discovery of oxygen and the beginnings of quantitative chemistry, the science was ready for Dalton's great discoveries respecting combination by weight, the corresponding discoveries by Gay-Lussac on combination of gases by volume, and, through the latter, for Avogadro's famous hypothesis Dalton had indeed, by reviving an old Greek suggestion, proposed to explain his discoveries by his atomic theory, but neither this nor our molecular theory, though the latter was inherent in the laws of gaseous combination of Gay-Lussac and in Avogadro's hypothesis, was finally put upon its present basis until Cannizzaro took up the subject half a century later Meanwhile Dulong and Petit had completed their studies of atomic heat, and Mitscherlich had pointed

out the relation between isomorphism and molecular structure. When it is considered how little is known of solid or liquid structure, and that our present knowledge of molecules is only of gaseous molecules, it is fortunate that these methods of study of solids are available. The same may be said of the results of the work of Kopp and his successors on molecular volumes. Of other aids to fixing our conception of molecules and atoms I need only refer to the periodic law, the studies of the properties of dilute solutions, of electrolytic dissociation, and of surface tension of liquids.

Liebig, in his first inquiry, begun before he went to Gay-Lussac in Paris, proved that silver fulminate and silver cyanate, though distinct substances, had exactly the same composition; thus was opened that great chapter in the history of chemistry which Berzelius named isomerism. Perhaps nothing in chemistry has given rise in recent years to more intellectual and practical activity than isomerism. Wöhler's classical synthesis of urea, by the metastasis of ammonium cyanate, added another instance of isomerism, and Berzelius soon afterwards announced the isomerism of tartaric and racemic acids. Wohler's synthesis of urea, followed, as it was, by numerous other laboratory syntheses, showed that substances which occur in living organisms are not different from those which may be prepared artificially, and the old distinction between inorganic and organic chemistry disappeared—there is, of course, only one chemistry. The words, it is true, have survived, but only for reasons of practical convenience.

After isomerism the next great step forward in the study of intra-molecular structure was the discovery of groups partially individualised which are capable of remaining intact through many reactions. Gay-Lussac had previously noticed the Cyanogen group as common to cyanides; but it was the celebrated paper by Wohler and Liebig on 'The Radical of Benzoic Acid' which finally established the existence of compound radicals or groups such as benzoyl, and obtained for the theory of compound radicals the position in chemistry it now holds. Bunsen followed somewhat later with the discovery of cacodyl, and now such groups are almost innumerable. In many respects, by the experimental skill which it shows, the clearness of its logical method, and the beauty of its form and diction, this memoir is a model of what a scientific communication should be. I will read the opening paragraph, using Hofmann's translation. 'When a chemist is fortunate enough to encounter, in the darksome field of organic nature, a bright point affording him guidance to the true path by following which he may hope to explore the unknown region he has good reason to congratulate himself, even though he may be conscious of being still far from the desired goal.' Of this memoir Berzelius, in a letter quoted by Hofmann (Faraday lecture), says: 'The facts put forward by you give rise to such considerations that they may well be regarded as the dawn of a new day in vegetal (organic) chemistry.'

The history of the advance of chemistry since the days of the Giessen laboratory is bewildering in its extent. This has been largely due to the Giessen laboratory itself, which sent trained investigators, each carrying with him some touch of its master's magic, into all civilised lands. I cannot attempt to even catalogue the results here. One thing may be said, that chemistry is not worked out, as some have thought; but rather the opportunities of discovery seem greater and more promising than at any previous period.

PART II.

Sub-atoms, atoms, molecules, molecular aggregates; valency.

Whether in the light of recent researches it may become necessary to give up that portion of Dalton's theory of atoms in which he regards them as undecomposable and indivisible, or whether we may consider them, as Prout suggested a hundred years ago, as different aggregates of sub-atoms of a uniform kind of matter, or whether they must be regarded as complexes built in the manner supposed by the electron hypothesis, also what should be our attitude towards the related problem of transmutation—all this I pass over, the more willingly that these subjects were discussed so recently by so high an authority as Sir William Ramsay in his address to the Association last year at Portsmouth.

I assume that we are fairly satisfied with our present atoms and their

respective weights, and this no matter how the atoms are constructed and that we shall be satisfied with them so long as they disport themselves in chemical changes as indivisible entities And further, I assume that we are satisfied with our molecules and their respective weights, as determined by the application of Avogadro's hypothesis Whether the molecular weight is obtained by direct determination of gaseous density or by taking advantage of the properties of dilute solutions, in either case the molecular weight which results is the weight of a supposed gaseous molecule, for the latter method depends for its justification on the former All our molecular weights are weights of molecules in the gaseous state or are supposed to be; they are not necessarily applicable to liquids, and much less to solids solids and liquids may well consist of far more complex particles

Gradually the central problem of chemistry has become more and more the study of the internal structure of molecules—of gaseous molecules The enormous number and variety of the compounds of carbon, with which so many workers have enriched the science during the last hundred years, and the special adaptability of these compounds to the experimental study of molecular structure, has led investigators to make use of them rather than of the so-called inorganic compounds thus out of inquiries into the intramolecular structure of these compounds arose and were developed the theories of types of Gerhardt, Williamson and Kekulé These are now, however, looked upon more as aspects of the general problem More fruitful has been the study of the compound radicals or individualised groups of Wohler and Liebig But gradually these molecular structures have been regarded, in agreement with the views of Dumas, as complete wholes, like fairy temples, which from different points of view show different parts in relief, accentuating, it may be, this or that column or frieze or pediment Kekulé's brilliant and suggestive theory of chain compounds and ring compounds did more than any other theory to guide and stimulate research in chemistry in recent times Like Gay-Lussac's theory of gaseous combination, though built in the first place only upon a few facts, this theory has proved true of the thousands of others with which we have since become acquainted, there seems indeed to be a need of a new psychology to account for such truly marvellous foresight as is here exhibited The atoms forming these varied structures were, however, regarded as being arranged in a plane, until the great discoveries of Pasteur made it necessary for chemists to extend their conceptions and to frame hypotheses of three dimensions Thus have arisen in the hands of Le Bel and van't Hoff and others our modern theories of stereo-chemistry When isomerism occurs in an element Berzelius names it allotropy It seems to me that now, when molecules of the elements do not differ essentially from molecules of compounds, there is no longer any distinctive meaning in the term, and that it might well be abandoned I would like also to make another suggestion respecting nomenclature that when we distinguish ring compounds as *cyclic* we might appropriately adopt the word *hormathic* (from the Greek word for a chain or a row) for chain compounds

But in order to understand the linking of atoms in these molecular edifices some combining value had to be assigned to the different atoms This idea of valency of the atoms was, no doubt, implied in Gerhardt's theory of types, but it did not gain much attention until later, when Frankland and Kolbé formulated an empirical theory of variable valency Kekule thought that atoms could not vary in their valency, but the alternative formulæ which he put forward to explain cases of difficulty would appear to be, rather, an attempted explanation of variable valency It might be more correct to say that Kekulé's formulæ constitute an anticipation of Werner's theory of auxiliary valencies, the theory which seems to find most favour at the present day Fixed valency can scarcely now be defended, in view of the existence of such compounds, for example, as the two fluorides and the two chlorides of phosphorus, the two oxides of carbon, ammonia and ammonium chloride, and, for example, the two series of compounds respectively of iron, mercury and copper Variable valency of atoms is empirically, at least, an established fact

By the latest conceptions of variable atomic valency and its extension almost without limit—so that, for example, oxygen may be regarded as quadrivalent and even sexivalent—no doubt the existence of numerous compounds which

previously presented difficulties can be explained There are, however, others long known to chemists, such as double salts and the combination of water with salts, formerly called 'molecular compounds,' definite and individual, in which these views do not assist us These compounds do not exist as gases, and unless they admit of experimental study by the methods of dilute solution, even their gaseous molecular weights cannot be ascertained

It is noteworthy that in most of the instances recently investigated where variable valency has been assumed the compounds studied have been easily decomposable solids or liquids, and for one reason or another their gaseous molecular weights could not be determined Many of these compounds, indeed, only exist at low temperatures As instances of work of this kind I may mention Collie and Tickle on quadrivalent oxygen in dimethylpyrone derivatives, Gomberg on triphenylmethyl, Landolf on acetone di-hydrofluoride, Thiele and Peter on methyl-iodo-dichloride, and similar studies by Kehrmann, Willstatter and Iglauer, Bulow and Sicherer, Baeyer and Villiger, Archibald and McIntosh, Chattaway, Pfeiffer and Truskier, and others

Another most interesting class of solids which are capable of existing in two isomeric forms distinguished from each other by such physical properties as density or colour are the Schiff's bases or anils Some of these were studied by Hantzsch, who proposed to explain their existence by the Hantzsch-Werner stereo hypothesis .—

$$\begin{array}{r} HO.C_6H_4.CH \\ \| \\ NR' \end{array} \qquad\qquad \begin{array}{l} HC.C_6H_4OH \\ \| \\ NR' \end{array}$$

But since only a few, and these not very satisfactory compounds, show this isomerism, which do not contain the hydroxyl group, other suggestions have been put forward to account for the isomerism, by Anselmino and by Manchot

In my own laboratory, associated with Mr F. G Shepheard and also with Miss Rosalind Clarke, I have made a study of various Schiff's bases for the purpose of investigating the remarkable property which some of these bases exhibit of *phototropy* By phototropy is meant the capability of reversible change of colour in solids depending upon the presence or absence of light Incidentally, too, I wished to study another physical property which many Schiff's bases possess, in common with other substances, of reversible change of colour with raising or lowering of temperature This property we have called *thermotropy*, and many old instances will be remembered of substances of simpler constitution which exhibit it thus, when subjected to the temperature of solid carbon dioxide, ordinary sulphur becomes colourless, red oxide of mercury becomes yellow, vermilion becomes scarlet, and on return to the ordinary temperature the original colours reappear

As has been pointed out in a recent communication by Bilman, it is most important in these discussions that we should be perfectly clear in the use of terms I take it for granted that *isomerism* is a general term for compounds differing in some respect but having the same composition If the molecules (gaseous) have the same weights they are *metamerides*, if of different weights they are *polymerides* When solids crystallise in more than one form they are *polymorphous* Now it does not seem reasonable to suppose that reversible colour changes such as those exhibited by phototropes or thermotropes involve such violent intra-molecular changes as the breaking and reconnecting of atomic linkages For example, take the three bases, salicylidene-*m*-toluidine, which in the dark or immediately it is exposed to light is yellow, but on continued exposure to light quickly becomes orange, and changes back again to its original colour in the dark, salicylidene-*m*-aminophenol, which at ordinary temperatures is orange, but is much paler at the temperature of solid carbon dioxide, on raising the temperature to nearly the melting-point (128·9°) becomes orange red, and these changes take place in the reverse order again on cooling; salicylidene *p*-aminobenzoic acid, studied by ourselves and by Manchot and Furlong independently, shows a wider range of thermotropic change between bright yellow and blood-red, and is also phototropic.

To explain such changes as these and the others of a similar nature previously referred to, I think some less drastic hypothesis should be sought than intra-

molecular breaking, and consequent metastasis or polymerisation. Though doubtless the hypothesis of Hantzsch and Werner could be invoked, or the modified hypotheses of Manchot or Anselmino, I think there should be some simpler explanation Someone suggests polymorphism. Now polymorphism means that a change of crystalline form takes place, which might doubtless connote change of colour. If one watches phototropic crystals changing colour under the influence of light from yellow to red, and notices that after remaining in the dark the same crystals have changed back to the original colour—and, remember, these changes can be repeated with the same crystals apparently without limit—it will not be considered likely that this phenomenon depends on a reversible change of crystalline form In a communication to the Chemical Society some three years ago Mr. Shepheard and I put forward the following suggestion 'Evidence is accumulating of reversible isomeric reactions, like those described in this paper, which are indicated by physical differences, such as changes of colour. It is possible that these may be explained by hypotheses, similar to that of Hantzsch and Werner assuming intra-molecular rearrangement, but in the case of phototropy and thermotropy it should not be forgotten that the substances exhibiting these phenomena are solids No one will doubt, however, that these differences of colour depend on isomeric change of some kind, but in the case of solids we know practically nothing of their molecules, not even of their relative molecular weights The molecules of solids are probably far more complex than those of liquids or gases, indeed, they may be rather complex groups or aggregates of ordinary gaseous molecules, which would give rise to far more numerous possibilities of isomerism. It appears to us that phototropic and thermotropic reactions are more probably due to isomeric changes affecting the aggregation of molecules in solids than to intra-molecular change of molecules derived from a study of gases'

It seems to me that just as atoms may be structures built of sub-atoms of some kind, and just as molecules of gases are built of atoms variously linked together, it is reasonable to conceive that molecules might combine to form aggregates, particularly when constituting solids, that as the sub-atoms may be conceived to have a combining valency, and the atoms are already accredited with this property, and in addition, as is supposed with Thiele's partial or Werner's auxiliary valencies, molecules may have valencies also whereby to combine into molecular aggregates It may be presumed that such aggregates are more complicated in structure, and thus may give rise to greater variety of isomerides, and be more readily transmutable than gaseous molecules If such aggregates of gaseous molecules exist they might explain not only the easily changed isomerides recently studied, but also the large class of 'molecular compounds' of the older chemists I imagine someone saying that in suggesting this hypothesis—which by the way is not new, for it is mentioned in Ostwald's 'Outlines'—I am violating the canon to which I have myself subscribed, as a condition of a scientific hypothesis, that it should be verifiable Perhaps we carry our critical faculty sometimes too far It is most highly scientific to doubt, but doubt which is merely destructive has little value, rather, with Descartes, it should lead on to construction, for he who builds even imperfectly is better than he who simply destroys And I do not doubt that some way will be found to study solids and obtain data that will lead to the determination of their molecular aggregate weights The study of molecular volumes of solid solutions, the remarkable results obtained by Pope and Barlow, Tutton's work on crystallography, and much besides, induce the hope that some day solids like gases will find their Avogadro

Part III

In the pursuit of all this abstract theory, and still more so in the bewildering multitude of undigested individual facts, there is danger that important and fundamental, even moral, considerations may be lost sight of. For example take the fundamental question, Why should we pursue chemistry? No doubt it is considered by its votaries, those who seek in our laboratories to advance the science, that they are entitled to have provided for them, and will be rewarded by the provision of, the ordinary means of livelihood; but these, it will scarcely be denied, could generally be far better assured by other pursuits It is suggested that intellectual discipline is a reason, but, I ask, for what purpose? Will

Pursuit of Chemistry justified by its useful applicability.

anyone pretend that intellectual discipline without utilitarian object, without the possibility of using it for the betterment of society, is a worthy pursuit? I think not But, in any case, none of us have devoted ourselves to chemistry merely for the sharpening of our wits. Again, someone suggests that chemistry and learning generally should be pursued for their own sake. In a recent most interesting and inspiring academic address[1] Professor Sir Walter Raleigh commends 'those who seek nothing from knowledge but the pleasure of understanding.' If such a statement bears its most obvious meaning, then I venture to think that, in common with intellectual discipline without the intention of applying to a useful object the intellect so trained, such a reason is selfish, inadequate, and unworthy, and does not justify the pursuit of anything No research in chemistry apart from the possibility of applying it to the advantage of humanity cannot be defended. The mastery of the seemingly unlimited resources of Nature which chemistry achieves more and more and its use to alleviate the misery and add to the happiness of mankind is the only worthy and effective defence And that this is the underlying ideal, in point of fact, that leads the chemist onward, not necessarily that he is always conscious of it, but always when he reflects, I think cannot be doubted But, of course, no narrow idea of utility must be aimed at. Practically any chemical inquiry may lead to results of material advantage Certainly nothing could be more mischievous than to make a narrow immediate utility the test It would be easy to illustrate all this from the records of science, but instances in point are so well known that it is unnecessary.

On the other hand, it should not be forgotten that in making use of the manifold advantages derived from the growth of science, humanity, on its part, owes a great debt to scientific inquirers, and ought to feel it a sacred duty to do in return all in its power by support and encouragement to further scientific research As Sir Walter Raleigh, in the address already referred to, says 'It is so easy to use the resources of civilisation that we fall into the habit of regarding them as if they were ours by right They are not ours by right, they come to us by free gift from the thinkers'

That this advantage to civilisation has been, and is, the result of the pursuit and consequent advance of chemistry is happily a truth that is well known

Some concrete applications of the Science.

There is scarcely an industry or a profession that has not been materially influenced or even created by the discoveries of chemistry, and therefore the welfare of nations is most intimately concerned in promoting its advancement Now, it is common knowledge that no country has appreciated this to the same degree as Germany It will, therefore, be worth our while to consider a moment the inauguration in Berlin, a year ago, of an entirely new institution, the Kaiser Wilhelm Institut, for the promotion and organisation of chemical research This research is to be effected throughout the German Empire, in the universities, the technical high schools, or in works, and it is supported mainly, at least at first, by subscriptions of the chemical manufacturers An address of very great importance was delivered at its opening by Professor Emil Fischer, than whom, perhaps, no one living has added more to the progress of chemistry A translation of this address appeared in 'Nature,' and, with additions, has since been published in a convenient book form[2] In this address an authoritative account is given of the main contributions of chemistry to the national welfare, which even to those familiar with the subject must be astonishing in their importance, variety, and universality It includes the applications of the science to problems of nourishment, to agriculture, and food supply, to engineering, metallurgy, cements; to clothing, artificial silk, or to colouring—dyes, to indiarubber production, both natural and artificial, to perfumery—artificial violet and other artificial floral perfumes, even that of the rose; to synthetic camphor; to drugs and synthetic materia medica, including the recent arsenic and selenium organic compounds which promise so much in the treatment of cancer and other fatal diseases; to radio-activity, to therapeutics, to the destruction of pathogenic microbes; to methods of sewage disposal; to the preparation of efficient explosives; and to

[1] *The Meaning of a University* Clarendon Press, 1911

[2] *Chemical Research in its Bearings on National Welfare.* London, 1912.

many other useful objects. In connection with the manufacture of explosives the public should know that the ability to wage war is becoming more and more dependent on the work of chemists. When the supply of mineral nitrates is exhausted, or even before that event, the requisite nitrogen compounds will have to be provided in some other way, and almost certainly they will be obtained synthetically from the atmospheric gases which even now are becoming a commercial source.

The Time-spirit and Science.

But students of history know that there are certain periods that for some unexplained reason are specially fruitful in certain departments of intellectual or artistic development. Professor Sir Walter Raleigh, for instance, a high authority on this subject, says: 'The human body, so far as we know, has not been improved within the period recorded by history, nor has the human mind, so far as we can judge, gained anything in strength or grace.' Further, regarding literature: 'The question is not by how much we can excel our fathers, but whether with toil and pains we may make ourselves worthy to be ranked with them.' Again: 'In the beautiful art which models the human figure in stone or some other enduring material, who can hope to match the Greeks? In the art of building who can look at the crowded confusion of any great modern city, with all its fussy and meaningless wealth of decoration, like a pastrycook's nightmare, and not marvel at the simplicity, the gravity, the dignity and the fitness of the ancient classic buildings? How can the seasoned wisdom of life be better or more searchingly expressed than in the words of Virgil or Horace, not to speak of more ancient teachers?' Thus all things are not progressing. The time-spirit now, and for some two centuries past, seems to have chosen to take under its particular guardianship the physical and natural sciences, their cultivation and applications, rather than philosophy or architecture or sculpture, or painting or literature. We shall do well to recognise this, and not waste our resources in striving to fight against it.

Present indiscriminate elementary teaching and neglect of research.

Large sums of money are expended in this country on the diffusion of some knowledge of chemistry among all classes of scholars and students, in fact, scarcely anyone escapes from a smattering, largely undigested if not indigestible, either forced on them by regulations or by the allurement of bribes in the form of prizes, scholarships, or academic laurels. And if this is not good for scholars or students, it is worse for masters or professors. Our professors work 'whole time' at this 'stall-feeding' process and if they happen to be strong men mentally and physically they may be able when weary with work to devote any overtime to—what I submit is far the more important matter for the State—the advancement of science by research. But this pursuit requires, for its successful prosecution, for resource and initiative to be at their best, that all the faculties should be in readiness in their fullest strength, freedom, and adaptability. How many, alas! are not strong men, and in their praiseworthy endeavours, notwithstanding, to contribute something to the achievements of their time succumb as martyrs to their devotion. The truth of this statement, I fear, is too well known to many of us here. In Germany this strain of elementary teaching is more recent, and is only now being felt. Professor Emil Fischer in his address (*loc. cit.*) says of it: 'During the last ten years a scheme of practical education of the masses has developed.' 'But this very education of the masses tends mentally to exhaust the teacher, and to a great extent, certainly to a higher degree than is desirable or indeed compatible with the creative power of the investigator, there prevails in modern educational laboratories a condition of overstrained activity.' And again, 'In the harassing cares of the day the teacher too readily loses that peace of mind and broad view of scientific matters necessary for tackling the larger problems of research.' Laboratories, he says, are wanted 'which should permit of research in absolute tranquillity, unencumbered by the duties of teaching.' I have given these quotations from Professor Fischer's address as indicating the matured judgment of a highly competent authority, communicated in the presence of the German Emperor on an historic occasion. His words are words of great weight, and no country which regards its future welfare can afford to ignore them.

Sir Walter Raleigh (*loc. cit.*) says that every university is bound to help the

poor . . but that does not mean that a university is doing good if it helps those who have no special bent for learned pursuits to acquire with heavy labour and much assistance just so much as may enable them to pass muster, on the contrary, it is doing harm I would like to invite the attention of all who are seriously interested in the country's welfare to reconsider the present policy in the teaching of chemistry, and this applies also to other sciences For the advancement of civilisation, for the increased welfare of the race by the technical applications of our science, it is not the indiscriminate teaching of the masses and the multiplication of examinations that is wanted, but the training of the few, of capable investigators I do not propose necessarily that we should interfere with, or much less abandon, much of our present elementary teaching, and I know that elementary, largely technical, training in chemistry is needed for medicine and engineering; but I do propose that our first endeavour should be to secure under present conditions in the present college or works laboratories, or in laboratories to be specially provided, that capable men, of whom we have many, should be able to devote themselves to research without the worry of teaching and examining or of providing the ways and means of livelihood There is, happily, reason to believe that this vital need is to some extent becoming known; for there have been several recent instances where a particular investigator has been afforded the means, financially, of prosecuting his particular researches in tranquillity The diversion of endowments to such purposes, instead of their going to the foundation of additional school or undergraduate scholarships, cannot be too highly commended

We may learn a lesson which bears on this from that remarkably prolific period of our science, the close of the eighteenth and the beginning of the nineteenth centuries It was then no easy matter to pass the precincts of a chemical laboratory, only the fittest survived the ordeal At the beginning of the nineteenth century the traditions of Berthollet and Lavoisier in Paris were kept alive by Gay-Lussac, in England those of Cavendish and Priestley by Davy, and Berzelius in Sweden worthily maintained the older school of Bergmann and Scheele By a happy fate the interest of Alexander v Humboldt was the means of both Liebig and Dumas being admitted to the intimacy of Gay-Lussac, and in Sweden Wöhler was fortunate to gain the confidence of Berzelius, and in London, Faraday that of Davy The achievements of these men—Liebig, Dumas, Wohler, and Faraday—are part of the history of science To me they contain a lesson, in point, of great importance The opportunity offered them was beset with difficulties No bribes such as scholars or students expect to-day were offered them, they knew no examinations, and their available apparatus and laboratory equipment was of the smallest and crudest description, but they were eager students with whom the master was in sympathy, and it is common knowledge that they completed the foundations of our science Now I ask, considering the thousands of students whom we teach and examine to-day, are we doing as well in the interest of the country as our predecessors a century ago? Who can confidently answer in the affirmative? No, whatever else is done, the country needs the provision of men whose untrammelled energy should be devoted to original chemical research Even as intellectual discipline the value of research is of the highest importance In his address to the British Association at Winnipeg, Professor Sir J J Thomson bears testimony to this He says 'I have had considerable experience with students beginning research in experimental physics, and I have always been struck by the quite remarkable improvement in judgment, independence of thought, and maturity produced by a year's research Research develops qualities that are apt to atrophy when the student is preparing for examinations, and, quite apart from the addition of new knowledge to our store, is of the greatest importance as a means of education'

And the object and ideal is wrong also in our system of technical training We aim too much at giving elementary instruction to artizans, which, though important in itself, can never take the place of the higher education of leaders or managers of industrial works This is different in Germany, where, although the training of artizans is by no means neglected, the chief energy is directed to the training and teaching of the smaller class of managers There is, too, in Germany a far more intimate relation between academic and industrial work, and the leaders in each often interchange posts In one respect we have an

advantage over Germany, it is important that this should be understood. The higher technical instruction across the Rhine has not been undertaken by the universities, but is carried out in separate institutions. With us the universities have gradually undertaken, in addition to the older technical subjects, theology, medicine, and law, the various branches of engineering and agriculture, and even commerce. This, it is to be hoped, will be extended so that the highly trained technologist may have the advantage of the undoubted humanising influence of the university.

Conclusion. I have not attempted in this Address any complete survey of chemistry, either its growth in the past or its present condition, but I have endeavoured to give some account of the sort of thing chemistry is—of its method—and to maintain three theses. (1) That the logical method by which chemistry advances is not a simple one, and requires as one essential element the use of a highly developed imagination. To render this more efficient I have advocated special training. (2) Without violating, I hope, the canons of the proper use of hypothesis, I have proposed, in order to account for certain isomeric and other phenomena, the conception of solid molecular aggregates, although I am not able at present to indicate precise methods for its further investigation. These molecular aggregates are supposed to be formed by the combination of gaseous molecules just as the latter are formed by the combination of atoms. (3) As a matter of vital interest to the continued well-being of this country I have insisted strongly that our educational resources devoted to chemistry should be directed, in the first place and chiefly, to the highest possible training of promising students in the prosecution of research, and that the giving to the many of elementary instruction should be at least a secondary consideration.

Now, I do not wish to dictate how this last proposition could be best carried into effect. I think we should distinguish three classes of chemists, or technical chemists, whose domains would more or less overlap. Occasionally there will be a man, like the late Sir William Perkin, who would combine all three. The three classes are: first, the pure chemist, devoted to scientific discovery only; second, the technical chemist, who prepares the discoveries of the pure chemist for the technologist, and has to determine such questions as economical production and, for example, the conversion of colours into dyes; third, the technologist or works manager. These three classes should be in close relation to one another. By such a scheme we should probably overcome by education one of our most serious present difficulties—the ignorance of owners of works of the value of science.

It is a matter deserving most earnest consideration whether, under the propitious influence of our own time spirit, it would be possible to organise research and develop it without interfering with its essential freedom and initiative, and this in each of the three classes I have mentioned, either by means of some of our existing institutions, or by the inauguration here of such an organisation as the Kaiser Wilhelm Institut in Berlin.

The following Papers and Report were then read:—

1. *Interaction between Thiocarbamide, Iodine, and Sulphur.* By Professor H. Marshall, *F.R.S.*

---

2. *The Distillation of Binary Mixtures of Metals in Vacuo.* By A. J. Berry, *B.A.*

Attempts have been made to isolate inter-metallic compounds in cases where one at least of the constituents is volatile by distilling alloys of the two metals containing an excess of the more volatile constituent in Jena glass tubes exhausted to the highest vacuum.

The success or failure of this method of isolating inter-metallic compounds clearly depends on two factors: (1) The tension of dissociation of the inter-metallic compound must be practically *nil* at the temperature at which the distillation is effected, and (2) the partial pressure of the vapour of the more volatile constituent must fall abruptly at the composition of the alloy corresponding

with the formula of the compound It would, therefore, appear *à priori* that success is likely to be realised in cases where the inter-metallic compound does not form solid solutions with either of its constituents The magnesium-zinc alloys constitute a system of this kind; these two metals form the well-defined compound $MgZn_2$ The author has shown[1] that this compound can be prepared by distilling alloys containing an excess of zinc beyond that required for the compound $MgZn_2$, the excess of zinc volatilising and the alloy of minimum vapour pressure consisting of the compound It has further been shown that, under suitable conditions, this compound can be distilled without decomposition.

Attempts have been made to investigate the volatilisation of mixtures in which the compounds can form solid solutions with their constituents Although no general conclusions have yet been reached, the following results have been obtained —

(1) Copper and cadmium are quantitatively separable by volatilisation of the cadmium

(2) Magnesium and cadmium yielded a non-homogeneous distillate

3 *Report on Diffusion in Solids.* *By* C. H Desch, *D Sc*, *Ph D* —See Reports, p 348

4 *Sorption of Hydrogen by Palladium* *By* Dr A Holt

5 *The Causes of the Induction Period in the Interaction of Hydrogen and Chlorine.* *By* R de J F. Struthers

6 *The Chemical Nature of Uranium X, Radio-Actinium, and Thorium B.* *By* Alexander Fleck, *B Sc.*

Marckwald and Keetman's statement that thorium and uranium *x* could not be separated was submitted to as thorough a chemical examination as possible The chief method employed in the attempted separation of these two bodies was fractional precipitation, but in no case was it found possible to alter the concentration of the short-lived radio-element in thorium

Similarly radio-actinium and thorium and thorium B and lead were found to be two pairs of chemically inseparable elements

7. *Report on Solubility.* *By* Dr. J. Vargas Eyre

See Appendix II , p 795

FRIDAY, SEPTEMBER 6

Joint Meeting with Section K

The following Papers and Report were read .—

1 (a) *The Enzymes of Linum* (b) *Variation in the Flax Plant with Locality* *By* Dr J. Vargas Eyre.

2 *Variation in* Lotus corniculatus *By* Professor H E. Armstrong, *F R S*

3 *The Biochemistry of Flower Pigmentation* *By* Professor F Keeble *and* Dr E F. Armstrong

[1] *Roy Soc Proc.*, A., vol 86, 1911, p 67

4 *Report of the Committee on Plant Enzymes* —See Reports, p 115.

---

5 *The Distribution of Oxydases in White Flowers.*
By W NEILSON JONES, *M A.*

In a recent communication to the Royal Society (Keeble and Armstrong) it has been shown that oxydases and peroxydases occur in the petals of flowers and elsewhere, and that their presence and distribution can be demonstrated by the use of benzidene and a-naphthol. Colour is produced by the action of these oxydases and peroxydases on a chromogen—*i e*, a colourless body which becomes coloured on oxidation

In white flowers absence of colour is presumed to be due to the absence of one or both these bodies, or to the presence of an inhibitor checking the action of the oxydase or peroxydase

The present investigation was undertaken in order to obtain further evidence as to the conditions which determine the absence of colour in white flowers

The evidence obtained points to the occurrence of the following types of white flowers —

(a) Those in which a chromogen and an oxydase both occur, but only react together after treatment with chloroform, ether, alcohol, &c This may be due to the localisation of chromogen and oxydase in different cells of the tissue, but still requires histological confirmation (*Cf* Guignard)

(β) Those containing chromogen and *peroxydase* with, presumably, a similar distribution, and requiring the addition of H_2O_2 to produce a reaction

(γ) Those containing a *peroxydase*, but no chromogen body with which it can react Such petals give a reaction with benzidene and H_2O_2

Types possessing (δ) an *oxydase* but no chromogen, and (ε) a chromogen without oxydase or peroxydase, have not yet been met with

A chromogen has been extracted from type (a) (after destruction of the oxydase by boiling) which can be used to demonstrate the distribution of peroxydase in, *e g*, petals of type (γ) in the same way as benzidene

The term chromogen as used above is applied to a colourless body which becomes coloured when acted upon by an oxydase or peroxydase It is fully realised that this extracted chromogen may not be identical with that responsible for the colour in the flower of coloured varieties of the same species.

---

6 *The Blackening of the Leaves of* Aucuba japonica.
By SYDNEY G PAINE, *B Sc*, *F I C*

The blackening of leaves of *Aucuba japonica* is due to the formation of a black pigment by oxidation of aucubeginin, which itself is a product of the splitting of the glucoside aucubin The blackening of the leaves under the influence of anæsthetics such as chloroform, toluene, alcohol, &c, was first shown by Guignard and Mirande, and it has been clearly proved by Maquenne and Demoussy to be due to the action of enzymes

These anæsthetic substances have been grouped together by H E and E F Armstrong as a class of *Hormones*, these workers apparently using the term hormone to signify any substance capable of activating an enzyme

Blackening of the leaves can, however, be brought about under conditions wherein the possibility of intervention of any such activating substance would seem to be very remote.

For example, leaves are blackened —

1 When heated to a temperature approximating to 60° C.

At 50 °C	blackening commenced after	46	min				
„ 5. °C.	„ „	28	„				
„ 54 °C	„ „	6	„	and was complete in		21	min.
„ 56 °C	„ „	4	„	„	„	7	„
„ 57 °C.	„ „	3	„	„	„	4	„

2. When submitted to a temperature below − 7° C

3 When dried in air

4 When partially dried in an atmosphere with vapour tension less than that of the cell sap

5 When dried *in vacuo* over sulphuric acid and subsequently immersed in water.

Further blackening occurs in solutions of salts such as sodium chloride, sodium sulphate, &c., which are not considered as hormones by Professor Armstrong The time of blackening of leaves immersed in such solutions varies with the concentration of the solution A similar variation in time of blackening also occurs when leaves are immersed in varying concentrations of alcohol

These experiments show that not only anæsthetics but a variety of other agencies are capable of producing the blackening in question The only character which these agencies appear to have in common is, not that they are activators of enzymes, but that they bring about those complex changes which, owing to the fact that they mainly await analysis, have to be classed together as *death* of the tissues It follows then that the blackening is probably a secondary phenomenon related to the death or injury of the leaf

It is well known that in the case of the plant-cell one of the most striking changes which occur at death is a great increase of permeability of the cell The simplest explanation, then, of the blackening, and the one most consistent with the present state of our knowledge, would seem to be that put forward by Maquenne and Demoussy in 1910, that the blackening occurs as a result of changes of permeability within the tissue, whereby the enzymes are brought into intimate contact with their substrates

7 *Action of the Enzymes of Emulsin on Amygdalin and Vicianin* *By* A. Compton

MONDAY, SEPTEMBER 9

Joint Discussion with Section A on the Atomic Heat of Solids

See p 407.

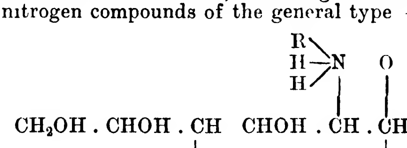
The following Papers were then read —

1 *Synthetic Aminoglucosides* *By* Professor J C Irvine *and* A Hynd, *M A* , *B Sc*

In recent publications[1] the authors have described the preparation of bromotriacetylglucosamine hydrobromide and the use of this compound in preparing a methylglucosamine which was shown to be α-aminomethylglucoside Further experiments have now indicated that bromotriacetylglucosamine is a general reagent for the preparation of α-aminoglucosides, as it enters into reaction with widely different types of hydroxy-compounds giving, in the first instance, acetylated aminoglucosides from which the acyl groups may be removed by hydrolysis

So far as is known at present, the α-aminoglucosides thus obtained do not occur naturally, and they are distinguished from unsubstituted natural or artificial glucosides by their alkalinity, their capacity to form additive salts with acids, and their behaviour towards hydrolytic reagents Some of the compounds are remarkably stable, and are only decomposed into a salt of glucosamine when strongly heated with concentrated acid In such cases the compounds are also unaffected by enzymes, and form molecular complexes with metallic halides

From these and other considerations, α-aminoglucosides of this nature are regarded as cyclic nitrogen compounds of the general type —



[1] *Chem Soc. Trans* , 1911, **99**, 250; 1912, **101**, 1128.

Where R is a group of low molecular weight As examples of this class we have α-aminomethylglucoside, α-aminoethylglucoside, and α-aminoamylglucoside

A second type of α aminoglucoside is formed when the group coupled with the glucosamine residue contains a benzene ring, as hydrolysis then proceeds normally with dilute mineral acids or with enzymes Representative members of this class, to which the usual glucosidic formulæ may be applied, are α-aminohelicin and α-aminosalicin

No general account of the preparation of α-aminoglucosides can be given, as the method has to be varied to suit individual cases When the hydroxy-compound is readily volatile, a large excess may be employed, and the reaction is carried out in the presence of morphine, which removes the hydrogen bromide formed in the change On adding the finely powdered bromotriacetylglucosamine hydrobromide, a considerable rise of temperature takes place, and the condensation is complete in a few minutes The isolation of the acetylated aminoglucoside is then conducted as already described by us[2]

In the case of high-boiling hydroxy-compounds the reaction may be carried out as described above, and the crude product precipitated by the addition of ether, or, when the solubilities permit, the condensation is conducted in dry ether containing pyridine, the solution being shaken with the solid bromo-compound for several hours In such cases the product separates in the course of the reaction These and other variations of the method were necessary when solid hydroxy-compounds were employed The removal of the acetyl groups was effected by heating with methyl alcohol containing 1 per cent of hydrogen chloride In the course of the research, nine aminoglucosides have been examined The list includes morphine aminoglucoside which is an alkaloidal derivative of a new type

2 *The Constitution of Mannitol Triacetone*

By Professor J C IRVINE *and* MISS BINA MARY PATERSON, *B Sc*

The condensation of sugars or polyhydric alcohols with acetone involves the loss of the elements of water from the ketonic group and two hydroxyl groups, and is influenced in a marked fashion by the configuration of the hydroxy-compound Fischer, on the basis of experiments carried out with glycerol, ethylene glycol, and trimethylene glycol, came to the conclusion that the reaction involved hydroxyl groups attached to β-carbon atoms, but, for several reasons, this view cannot be applied generally In the case of reducing sugars especially, the reaction is complicated by several factors, including the fact that part of the molecule is a ring structure and thus presents the possibility of *cis* and *trans* condensation with the ketone The simplest conditions for a study of the reaction are thus available in the case of an active polyhydric alcohol, and we have, in the meantime, confined our attention to mannitol.

Although it is impossible to arrest the condensation of mannitol with acetone at intermediate stages, we find that by carefully regulated hydrolysis three molecules of the ketone can be removed successively from mannitol triacetone The reaction thus gives an index of the varying stability of the ketonic residues and proceeds according to the scheme :—

Mannitol triacetone ⟶ Mannitol diacetone ⟶ Mannitol monoacetone ⟶ Mannitol

In view of the extreme instability of the intermediate compounds, indirect methods had to be employed to determine their constitution. This was effected in each case by methylation and subsequent hydrolysis. The resulting compounds were thus alkylated in the positions from which the acetone residues had been removed, and the position of the methyl groups was finally determined by standard methods. The results are summarised below :—

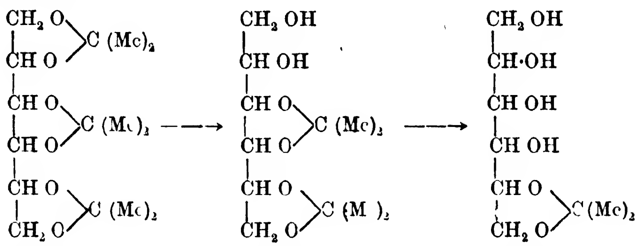
Mannitol diacetone was prepared by heating a solution of mannitol triacetone in 68 per cent. alcohol containing 0 1 per cent of hydrogen chloride The hydrolysis was continued at 40° for 150 minutes The compound melted at 37° to 39° and showed $[\alpha]_D^{20°}$ + 15° 7 in alcoholic solution (c=2 7). When methylated by the silver-oxide reaction it was converted into ***dimethyl mannitol diacetone***, a colourless mobile liquid boiling at 140° to 141°/13 mm. and showing $[\alpha]_D^{20°}$ + 21° 9 in alcohol.

[2] *Loc cit.*

This compound, when hydrolysed, was converted into a *dimethyl mannitol* (m p. 93°, $[\alpha]_D^{20^\circ} -8^\circ 8$ in alcohol) giving, on oxidation, a *dimethyl mannonic acid* which was identified by analyses of the calcium salt.

On the other hand, when the hydrolysis of mannitol triacetone, under the conditions described above, was continued for four hours, the main product was *mannitol monoacetone* (m p. 85°, $[\alpha]_D^{20^\circ} + 23^\circ 2$). This was converted into *tetramethyl mannito monoacetone* (b p. 137° to 140° /11 mm., $[\alpha]_D^{20^\circ} + 32^\circ 2$), and finally into *tetramethy mannitol* (b p. 167° to 169°/13 m.m $[\alpha]_D^{20^\circ} -12^\circ 5$). The latter, on oxidation with nitric acid, gave a *tetramethyl mannonic acid* (b p 180° to 182°/12 mm. $[\alpha]_D^{20^\circ} + 10^\circ 1$) which failed to give a lactone on repeated distillation. For the purposes of comparison, the isomeric *tetramethyl mannonic acid* was prepared from methylmannoside and found to be entirely different, as, on distillation, it was completely converted into *tetramethyl mannono-lactone* (b p 174°/11mm. $[\alpha]_D^{20^\circ}$ in dilute alcohol $+78^\circ 8 \rightarrow 27^\circ 5$).

A review of all the above results shows that in dimethyl and tetramethylmannitol the alkyl groups are present in positions 5 · 6 and 3 · 4 5 · 6 respectively, so that the structure of mannitol triacetone and its partial hydrolysis may be expressed by the scheme —



The linkage of each of the condensed groups is thus in the α-position throughout, but the order in which the acetone residues are removed is quite unexpected and involves complex stereochemical considerations.

Our results are supported by experiments recently made by Mr. J L. A. Macdonald who, in similar work, converted glycerol acetone into a *monomethyl glycerol* (b p. 109°/12 mm) which was identical with the compound obtained on decomposition of α · β dibromo— α methoxy—propane with silver acetate, and hydrolysis of the product.

It should however be mentioned that evidence was obtained that mannitol triacetone is either a mixture, or is capable of reacting in mo e than one form. When tetramethyl mannitol was oxidised by Fenton's reagent, the bulk of the material remained unaltered, but a small quantity of 2 · 3 : 5 · 6 tetramethyl mannose was formed which was identified by conversion into the anilide. A small quantity of material in which at least one acetone residue connected γ-carbon atoms must therefore have been present in the original specimen of the triacetone compound.

3 *The Rotatory Powers of partially Methylated Glucoses*

By Professor J. C. IRVINE *and* J. P. SCOTT, *M.A* , *D Sc*

During the past four years a number of partially alkylated sugars have been obtained by a variation of the method originally adopted by Purdie and Irvine [1] in the preparation of tetramethyl glucose, and we are now in a position to add a series of partially methylated glucoses to the list of compounds of this type.

The method of preparation adopted can be expressed in general terms. Glucose was condensed with various residues which could subsequently be removed by hydrolysis ; the unsubstituted hydroxyl groups were then methylated by the silver oxide reaction, and, on hydrolysis, a partially alkylated glucose was obtained. It was thus possible to protect selected groups from methylation, as shown in the following examples :—

Monomethyl Glucose.

Glucose diacetone, when methylated by the modified method described in the

[1] *Chem Soc Trans.*, 1903, 83, 1021.

case of fructose diacetone[2] was converted into *monomethyl glucose diacetone* (b p. 139° to 140°/12 mm, $[\alpha]_D^{20^\circ} - 32^\circ 2$ in alcoholic solution) When heated in aqueous alcohol containing 0 4 per cent. of hydrogen chloride the two acetone residues were removed simultaneously, and, on working up the product in the usual way, *monomethyl glucose* was obtained in good yield Both the α and β forms of the sugar were isolated, the former being deposited spontaneously from methyl alcoholic solutions, while the latter was precipitated from concentrated solutions in methyl alcohol by the addition of acetone

α form· Rectangular plates, m p 157° to 158° Mutarotation in aqueous solution —

$$[\alpha]_D^{20^\circ} + 96^\circ 7 \longrightarrow 55^\circ 5$$

β form· Acicular prisms, m p 130° to 132°. Mutarotation in aqueous solution —

$$[\alpha]_D^{20^\circ} + 31^\circ 9 \longrightarrow 55^\circ 1$$

The sugar was shown to possess the structure

$$CH_2OCH_3\ CHOH\ \underbrace{CH\ CHOH\ CHOH\ CHOH}_{O}$$

from the fact that it gave the same monomethyl glucosazone as that obtained from monomethyl fructose[3]

Monomethyl methylglucoside, prepared by Fischer's method, failed to crystallise, the specific rotation of the mixed α and β forms in alcoholic solution being +99° 3

Dimethyl Glucose

Methylation of benzylidene α methylglucoside gave an excellent yield of *benzylidene dimethyl α methylglucoside* (m p 122° to 123°; $[\alpha]_D^{20^\circ} + 97^\circ 0$ in acetone solution) By carefully regulated hydrolysis a molecule of benzaldehyde was eliminated and *dimethyl α methylglucoside* was formed (m p 80° to 82°, $[\alpha]_D^{20^\circ} + 142^\circ 6$ in aqueous solution) On complete hydrolysis the glucoside was converted into *dimethyl glucose*, which was isolated in α and β forms The β modification melted at 108° to 110° and separated in delicate needles from dilute solutions of the sugar in ethyl acetate, while the α variety (m p 85° to 87°) was obtained by the addition of dry ether to a concentrated solution in ethyl alcohol. The mutarotation of each was determined in pure acetone.

β form: $[\alpha]_D^{20^\circ} + 5^\circ 9 \longrightarrow + 50^\circ 9$ α form $[\alpha]_D^{20^\circ} + 81^\circ 9 \longrightarrow + 48^\circ 3$

The sugar, under conditions favourable to osazone formation, gave a *dimethyl glucosephenylhydrazone* and has thus the probable structure —

$$CH_2OH\ CHOH\ \underbrace{CH\ CHOCH_3\ CHOCH_3\ CHOH}_{O}$$

Trimethyl Glucose.

Glucose monoacetone was converted into *trimethyl glucose monoacetone* (b p 138° to 139°/12 mm), from which, on hydrolysis, *trimethyl glucose* was obtained The sugar failed to crystallise, and thus the specific rotation could only be determined for the equilibrium mixture of α and β forms ($[\alpha]_D^{20^\circ} - 8^\circ 3$ for both alcoholic and aqueous solutions). No solid glucoside, hydrazone, or other derivative could be obtained. The constitution, deduced from that of glucose monoacetone, is expressed by the formula :—

$$CH_2OCH_3\ CHOCH_3\ \underbrace{CH\ CHOCH_3\ CHOH\ CHOH}_{O}$$

Discussion of the Optical Results.

Ten out of the possible thirty-one methylated glucoses are now available for comparison. We find that the rotatory powers of these substituted glucoses are only slightly affected by changes in concentration or by change of solvent. Further, in the case of mutarotatory forms, accurate initial values can be determined in acetone solution, as the optical change remains suspended until a catalyst is added. We are

[2] *Chem Soc Trans* 1909, 95, 1223. [3] *Loc. cit.*

thus able to show that both monomethyl- and dimethylglucose conform to the generalisation established by C. S. Hudson [4] regarding molecular rotation in the sugar group. As the two sugars are substituted respectively externally and internally to the γ-oxidic ring, it would appear that Hudson's rule is applicable to certain types of substituted sugars and can be used for calculating the activity of unknown β forms or for the adjustment of approximate values determined experimentally On this basis the specific rotation of β-tetramethyl glucose becomes $+32°$ 16, a value which is consistent with the rotatory powers of the fully alkylated glucosides Hudson's rule cannot however be applied to benzylidene methylglucoside, a new isomeric form of which was isolated, on account of the introduction of a new asymmetric system into the molecule

Our results also show that the hydroxyl groups in glucose fall into two classes with respect to their influence on optical power, (*a*) those situated within the γ-oxidic ring, and (*b*) those external to the ring In class (*a*) the asymmetric systems in which the hydrogen atom is above, and the hydroxyl group below the plane of the ring, exert a dextro-rotatory effect Those in which the reverse arrangement exists are lævo-rotatory. Definite configurations can thus be suggested for the α- and β glucoses

The effect of methylating the hydroxyl groups of class (*a*) is to greatly intensify the rotation of the system to which it belongs, while in class (*b*) the effect is relatively small. If the groups are numbered according to the scheme —

$$\begin{array}{cccccc} & & \multicolumn{4}{c}{\overbrace{\hspace{14em}}^{O}} \\ CH_2OH & CHOH & CH & CHOH & CHOH & CHOH \\ (6) & (5) & (4) & (3) & (2) & (1) \end{array}$$

the deduction can also be made that the optical effect of methylating the hydroxyl group No 2 is to raise the rotation of glucose by an unknown amount (x) which is probably over 100 per cent

Methylation of No 3 depresses the dextro-rotation to the extent $x+20\ 7$ per cent. On the other hand, methylation in positions 5 and 6 contributes a rise in the dextro sense to the extent of 48 9 and 8 per cent respectively These numbers are arrived at by adopting as the standard of comparison in each case the value

$$\frac{[M]_D\ \alpha\text{-form} + [M]_D\ \beta\text{ form}}{2}.$$

The application of these quantitative results is now being tested in the case of partially alkylated mannoses and galactoses.

4 *Acetyl-halogen Sugar Derivatives*
By W Sloan Mills, *M A , D Sc , B E*

Acetyliodoglucose and acetyliodogalactose were prepared by me at Queen's College, Galway, and formed part of a thesis presented for a D Sc. degree to the Royal University of Ireland in 1906 As they were not published by me, Fischer has recently described[5] the former compound which he prepared, how ever, by a more indirect method

Preparation of β-acetyliodoglucose, $C_6H_7O(OAc)_4I$ —Hydriodic acid gas was generated by the action of water on iodide of phosphorus and dried by means of calcium chloride and phosphorus pentoxide A slow stream of the gas was passed into a solution of five grams of β-pentacetylglucose in 8 c c of dry methylene chloride contained in a small distilling-flask The gas was rapidly absorbed at first, and when fumes began to issue from the side-tube of the distilling-flask the supply was cut off and the side tube directly connected with a vacuum pump. The bulb was immersed in warm water till the methylene chloride and excess of hydriodic acid had distilled off The thick syrup remaining solidified on being touched with a glass rod moistened with alcohol It should be recrystallised as quickly as possible from the alcoholic solution, as both methyl and ethyl alcohol decompose it, the solution becoming acid.

It melts at 108° to 109° and readily yields acetyl acoholic and acetyl phenolic glucosides. Various attempts were made to prepare α-acetyliodoglucose from α-pentacetylglucose, but in all cases the β compound was isolated.

[4] *Journ. Amer. Chem. Soc*, 1909, 31, 66. [5] *Ber*, **43** (1910), 2521

β-acetyliodogalactose may be prepared from β-pentacetylgalactose in the same manner as the glucose compound It is much more difficult to obtain crystalline and much more readily decomposed by alcohol than the corresponding glucose compound. It can, however, be obtained in a beautifully crystalline condition by dissolving the syrup in carbon disulphide and allowing the solution to evaporate at ordinary temperature It melts at 93° to 94°

Octacetylmaltose when treated with dry hydriodic acid in methylene chloride solution also yielded an iodo derivative which when crystallised from a mixture of chloroform and ligroin melted at 62° to 66°, and yielded methyl-acetyl-maltoside (melting-point 121° to 122°) with methyl alcohol and silver carbonate

Acetyliodolactose was readily obtained even from impure acetyl-lactose by passing an excess of dry hydriodic acid into a solution of the acetyl compound dissolved in benzene Some syrup separated during the reaction, and the solution when shaken with water and sodium bicarbonate solution and dried with calcium chloride gave a copious crystalline precipitate of the iodo compound on the addition of absolute ether When recrystallised from a mixture of acetone and ether it melted at 142° C

For the preparation of those compounds methylene chloride and chloroform seemed to be the most suitable solvents A convenient method of testing the syrups obtained for iodine is to touch a portion of the syrup with a glass rod dipped in strong nitric acid, when it becomes black owing to the separation of iodine

The action of copper hydride was tried on acetyliodoglucose For this purpose four grams of freshly made acetyliodoglucose was mixed in a porcelain basin with an excess of freshly made copper hydride which had been washed with absolute alcohol and absolute ether The plastic mass was well stirred and left standing for three days, when it was extracted with chloroform The syrup remaining on evaporation of the chloroform was dissolved in hot dilute alcohol, from which a mass of crystals (0 9 gram) separated on cooling The mother liquor yielded a further crop of crystals and a syrup which could not be made to crystallise It was twice recrystallised from alcohol, from which it separates in long slender prisms, and melted at 104° to 105° It does not reduce Fehling's solution after being boiled with dilute sulphuric acid, or after being boiled with sodium hydrate and then dilute sulphuric acid

On analysis —

$$0\,1730 \text{ gram gave } 0\,3118CO_2 \text{ and } 0\,1010H_2O$$
$$C = 49\,16 \quad H = 6\,49$$
$$C_{28}H_{44}O_{19} \text{ requires } C = 49\,1 \quad H = 6\,47$$

A molecular weight determination has not yet been made This formula could be derived by assuming that the two glucose rests were united at the position held by the iodine atom and that the γ-oxide ring in each residue was reduced, giving a substance whose formula is $C_{28}H_{42}O_{18}$, which with one molecule of water of crystallisation would give the above formula

5 *Hexosephosphate* *By* Dr A Harden, *F.R S*

6 *Nomenclature of Optically Active Substances* *By* Dr E F Armstrong

7 *On the Dissociation of Phosphorous Vapour* *By* Professor Alfred Stock *and* G E Gibson, *Ph D*

Biltz and Victor Meyer have measured the vapour density of phosphorus at various temperatures At lower temperatures the vapour density corresponds to the formula P_4 At high temperatures they were able to detect dissociation.

Victor Meyer's method is, however, not suitable for the quantitative investigation of dissociating vapours, since the degree of dissociation is altered by the addition of an inert gas

The authors have determined the pressure temperature curves of phosphorus

vapour at various volumes, using quartz apparatus and the quartz membrane manometer devised by Gibson [1]

The vapour density corresponds to the formula P_4 up to about 700° C, above which dissociation takes place according to the equation:

$$P_4 = 2P_2$$

There is no evidence of further dissociation at the temperatures investigated The law of mass action applied to the new measurements decides against the equation

$$P_4 = 4P$$

The authors desire to thank Dr Erich Stamm for valuable assistance in the course of the research, and to acknowledge receipt of a research grant from the Carnegie Trust, from which part of the expense of the investigation was defrayed.

TUESDAY, SEPTEMBER 10

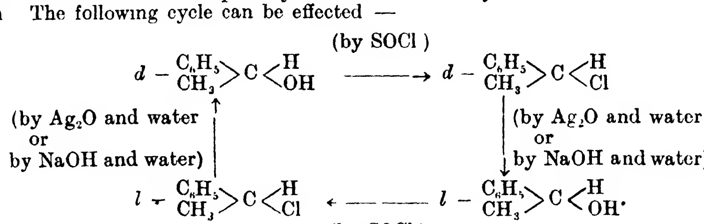
Discussion on the Migration of Groups

The following Papers and Reports were then read —

1 *The Walden Inversion* *By* Dr A McKenzie

2 *Interconversion of the Enantiomorphous Forms of Phenylmethylcarbinol* *By* Dr Alex McKenzie *and* George W Clough

Work on the Walden inversion has been hitherto confined practically entirely to changes undergone by carboxylic acids or their derivatives, esters, &c In the present communication it is shown that an optically active alcohol can be transformed into its enantiomorphously-related isomeride by the aid of a Walden inversion The following cycle can be effected —



On the other hand, the action of phosphorus trichloride on the *d*-carbinol is accompanied by a change of sign of rotation and the resulting *l* α-chloroethylbenzene is considerably racemised

Action of Thionyl Chloride on the Active Carbinols —*d*-Phenylmethylcarbinol was prepared by the resolution of the hydrogen *dl*-succinic ester by means of brucine according to the method of Pickard and Kenyon [2] It boiled at 104°/23mm and had $[\alpha]_D^{20} + 43° 36$, a value in agreement with that quoted by Pickard and Kenyon

The *d*-alcohol (4 grams) was added gradually to thionyl chloride (10 grams) The product was distilled under diminished pressure and the fraction boiling at 85°/20mm amounted to 4 grams It had $\alpha_D^{20} + 26° 90$ ($l = 0$ 5), d_4^{20} 1 0631, whence $[\alpha]^{20} + 50°$ 6 Found Cl = 25 3, calc 25 2 per cent.

The *l*-alcohol, obtained by decomposing the mother liquors from the crystallisation of the brucine salt of the hydrogen succinc ester, had α_D −26° 70 ($l = 1$), 41 grams was added as before to 56 grams of thionyl chloride The fraction boiling at 85°/20 mm. had $[\alpha]_D^{20}$ − 30° 15 Found Cl = 25 3; calc 25 2 per cent.

Action of Phosphorus Trichloride on d-*Phenylmethylcarbinol* —The *d*-alcohol

[1] Diss Breslau, 1911

[2] *Trans. Chem. Soc*, 1911, **99**, 45.

(5 grams) was added drop by drop to phosphorus trichloride (20 grams) cooled in ice The product was fractionated. The portion boiling at 80° to 80° 5/15 mm. had $\alpha_D^{18} - 4° 32$ ($l = 0$ 5), d_4^{18} 1 0638, whence $[\alpha]_D^{18} - 8° 12$. Found Cl=25 1; calc. 25 2 per cent.

Action of Silver Oxide and Water on l-*α Chloroethylbenzene* —Six grams of the partially racemised α chloroethylbenzene with $[\alpha]_D^{20} - 30° 15$ was added to 60 c c of water and the mixture shaken with silver oxide (6 grams) for two hours and then heated on the water-bath for fifteen minutes The alcohol was removed by distillation in steam, extracted with ether and fractionated The fraction boiling at 196° to 200° (2 grams) had $\alpha_D + 3° 71$ ($l = 0$ 5)

Action of Sodium Hydroxide and Water on l *α Chloroethylbenzene* —Six grams of α chloroethylbenzene with $[\alpha]_D^{20} - 30° 15$ were boiled for two hours with a solution of 6 grams of sodium hydroxide in 60 c c of water The alcohol was obtained as in the preceding experiment The fraction boiling at 196° to 200° (2 grams) had $\alpha_D + 0° 65$ ($l = 0$ 5)

The displacement of chlorine by the hydroxy-group is accordingly accompanied by more racemisation when sodium hydroxide is used in place of silver oxide

This work is being continued

3 *Report on Dynamic Isomerism.*—See Reports, p 115

4 *The Conversion of Chloro-, Bromo-, and Nitro-amino-benzenes into the C-substituted Anilines and Anilides* *By* Dr K J P Orton.

5 *On the Nitration of the Chlorotoluenes*
By Professor A F Holleman *and* J P Wibaut

6 *The Optical Activity of Leucine in presence of Varying Amounts of Acid and Alkali* *By* Dr J K Wood.

7 *The Action of Bromine on Strychnine*
By Professor C R Marshall, *M D*

8 *Pentaerythritol Tetranitrate*
By Professor C R Marshall, *M D*

9 *Phototropy and Thermotropy*
By Professor A Senier, *M D*

10 *Report on the Transformation of Aromatic Nitroamines*
See Reports, p 116.

11 *Report on the Study of Hydro-aromatic Substances.*
See Reports, p. 124.

12 *Report on Electroanalysis.*

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION.—B. N. PEACH, LL.D., F.R.S.

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

THE RELATION BETWEEN THE CAMBRIAN FAUNAS OF SCOTLAND AND NORTH AMERICA.

CONTENTS.

Introduction.

EVER since the announcement made by Salter in 1859 that the biological affinities of the fossils found in the Durness Limestone are more closely linked with American than with European forms, the relation between the older palæozoic faunas of Scotland and North America has been a subject of special interest to geologists. The subsequent discovery of the *Olenellus* fauna in the North-West Highlands furnished striking confirmation of Salter's opinion. This intimate relationship raises questions of prime importance bearing upon the sequence and distribution of life in Cambrian time in North America and North-West Europe, on the probable migration of forms from one life-province to another, and on the palæogeographical conditions which doubtless affected these migrations.

On this occasion, when the British Association revisits the border of the Scottish Highlands, it seems appropriate to refer to some of these problems. With this object in view I shall try to recapitulate briefly the leading features of the life history of Cambrian time in Scotland and North America, to indicate the relation which these life-provinces bear to each other, and, from these data, to draw some inferences regarding the probable distribution of land and sea which then obtained in those regions.

The two great rock groups in Scotland that are universally admitted to be older than Cambrian time are the Lewisian Gneiss and the Torridon Sandstone. The Lewisian Gneiss, as mapped by the Geological Survey, consists mainly of igneous rocks, or of gneisses and schists of igneous origin. But, in addition to these materials, we find, in the Loch Maree region, schists of sedimentary origin, comprising siliceous schist, mica-schist, graphite-schist, limestone, chert, and other sediments. The association of graphite-schist with limestone and chert suggests that we are here dealing with rocks that were formed at or near the extreme limit of sedimentation, where the graphite, the limestone, and the chert were probably accumulated from the remains of plankton. But this assemblage has been so completely altered into crystalline schists that all traces of original organic structure in them have been destroyed.

The Torridonian strata were evidently accumulated under desert or continental conditions, and could therefore furnish little or no evidence bearing upon the development of marine life. That life existed, however, is clear from the presence of phosphatic nodules, containing remains of cells and fibres of organic origin, in the upper division of the system, and from the presence of worm burrows and casts in the Diabaig beds (Lower Torridon).

Geologists are familiar with the fact that the Cambrian faunas all over the globe present highly specialised types belonging to most of the great groups of marine invertebrate life. Scotland is no exception to this general rule. For the fossils prove that their ancestors must have had a long history in pre-Cambrian time.

The Cambrian Fauna of Scotland.

Beginning with the false-bedded quartzites forming the basal subdivision of the Cambrian strata in the North West Highlands, we find no traces of organic remains in them, except at one locality, where worm casts (*Scolithus linearis*) were obtained. In the upper subdivision of the quartzites—the pipe-rocks—the cylinders of sand are so numerous that the beds have been arranged in five subzones, based on a definite order of succession of different forms probably of specific value. One of them, *Arenicolites* of Salter, may be of generic importance. Worms of this habit are confined to comparatively shallow water, and therefore near the shore line. Their occurrence helps to confirm the belief that the quartzites were laid down on an ancient shelving shore line during a period of gentle subsidence. Their presence also indicates the existence of plankton, from which they derived nourishment. Besides the relics of these burrowing annelids, one of the subzones of the pipe-rock has yielded specimens of *Salterella* (*Serpulites Maccullochii*)—a tubicolar annelid, which becomes more abundant in the overlying fucoid beds, serpulite grit, and basal limestone, where it is associated with *Olenellus* and other typical Lower Cambrian forms.

The fucoid beds, which immediately overlie the pipe-rocks, consist chiefly of shales and brown dolomitic bands, with intercalations of grit locally developed. This type of sedimentation indicates that the mud line was superimposed on the shore line by subsidence. With this change of conditions there is a change of organisms, for though the burrowing forms (*Scolithus*) are still to be found in the sandy layers, the most characteristic types are those occurring along the bedding planes, known under the name of *Planolites* (Nicholson). They are very varied forms, and were probably produced by many types of errant annelids. The tubicolar annelids are represented by *Salterella*, *Coleoloides*, and *Hyolithes*—an organism which perhaps links the worms with the hingeless brachiopods. This suggestion gains additional support from the researches of Dr. Walcott in the Middle Cambrian rocks of Canada. It is interesting to note that small annelids seem to have bored the spines of dead trilobites. Walcott has found similar borings in the chetæ of annelids in the Middle Cambrian rocks of Canada.[1]

The researches of Dr. Walcott have proved beyond doubt that representatives of nearly all the divisions of the annelids are entombed in the Middle Cambrian rocks of Mount Stephen, in British Columbia. We may therefore reasonably infer that the worm casts of *Scolithus* type found in the North-West Highlands are due to annelids. He has also shown that worm-like holothurians are to be found in the same beds.[2] In this connection it may be observed that some of the recent holothurians have much the same habit of obtaining nourishment from the sands and silts containing organic matter.

Fragments showing the characteristic microscopic structures of the plates and ossicles of echinoderms have been found in the fucoid beds. These are probably Cystidean. Hingeless forms of brachiopods also occur, among which may be mentioned *Paterina labradorica* and *Acrothele subsidua*. The type of *Acrothele* suggests a genetic descent from such a tubicolar worm as *Hyolithes*. Of the gasteropods, only one specimen, belonging to a subgenus of *Murchisonia*, has been obtained at one locality in Skye. *Helenia bella*, a curved calcareous tube, open at both ends, doubtfully referred to the *Dentalidæ* by Walcott, is comparatively plentiful. It occurs also in the *Olenellus* zone in Newfoundland.

[1] *Smithsonian Miscell. Collect.*, vol. 57, No. 5, p. 125, 1911.
[2] *Ibid.*, No. 3, 1911.

But the organic remains that render the fucoid beds of exceptional interest and importance are the trilobites, because they clearly define the horizon of this zone in the Cambrian system and display strong affinities with American types. They are represented by five species and varieties of *Olenellus*, very closely resembling the forms in the Georgian terrane, or *Olenellus* zone, on the east and west sides of the North American continent. The genus *Olenelloides* has also been recorded from these beds. The crustacea are represented by phyllocarids, among which we find *Aristozoe rotundata*, likewise characteristic of the *Olenellus* zone of North America.

Next in order comes the serpulite grit, which indicates a recrudescence of the pipe-rock conditions of deposition, and presents the *Scolithus* type of annelid borings. From the diameter of the pipe and the depth of the burrow it is probable that the worm may have belonged to a different species from any of those whose casts are to be found in lower horizons. This large variety is associated with smaller and more irregular worm casts which have often weathered out and left the rock honeycombed with hollow casts. The characteristic form from which the zone takes its name is *Salterella* (*Serpulites Maccullochii*). It occurs abundantly along certain calcareous layers that mark pauses in the deposition of the sand. This calcareous type culminates at the top of the zone, where there is a thick, carious, weathering band, crowded with specimens of *Salterella*, forming a passage bed into the calcareous shales at the base of the Durness dolomites. At one locality near Loch an Nid, Dundonnell Forest, Ross-shire, thin shales, intercalated in the serpulite grit, yielded a fine carapace of *Olenellus Lapworthi*—a form of frequent occurrence in the underlying fucoid beds. Professor Lapworth recorded the finding of *Orthoceras* and linguloid shells in the top part of this zone at Eireboll.[3]

Immediately above the serpulite grit in Eireboll and Assynt we find a few feet of dark calcareous shale, with iron pyrites, probably deposited at the limit of sedimentation. This layer, which is singularly devoid of organisms, ushers in the great succession of dolomites and limestones, upwards of 1,500 feet in thickness—perhaps the most remarkable type of sedimentation among the Cambrian rocks of the North-West Highlands. The Geological Survey has divided this calcareous sequence into seven well-marked groups, some of which have as yet yielded no fossils beyond worm casts. Attention will presently be directed to the absence of calcareous forms in many of the bands of dolomite and to the probable cause of their disappearance.

The thin calcareous shale just referred to is followed by dark blue dolomite limestone, forming the basal portion of the Ghrudhaidh group. It contains sparsely scattered, well-rounded sand grains, with a bed about three feet thick, near the bottom, charged with *Salterella pulchella* and *S. rugosa*. In the overlying twenty feet of dolomite the sand grains gradually disappear, and the rock assumes a mottled character, due to innumerable worm casts of the *Planolites* type. Here a second layer, yielding *Salterella pulchella* and *S. rugosa*, supervenes, both forms occurring in the *Olenellus* zone of North America.

The brief summary of the palæontological evidence which has just been given clearly shows that the strata ranging from the middle of the pipe-rock zone to the upper *Salterella* band of the Durness dolomites represent in whole or in part the *Olenellus* zone of North America. Owing to the absence of fossils we have no means of deciding more definitely the base and top of the Lower Cambrian rocks of the North-West Highlands. All the quartzites lying below the middle of the pipe-rock, notwithstanding the absence of zonal forms, have been included in the Lower Cambrian division. This correlation receives some support from the remarkable discovery of Dr. Walcott, who found primitive trilobites several thousand feet beneath the beds yielding *Olenellus Gilberti*, the form closely allied to the Highland trilobites.

On the other hand, when we pass upwards for a certain distance from the *Salterella* bands the evidence is insufficient to establish the stratigraphical horizon of the beds. For in the overlying strata, comprising the remainder of the Ghrudhaidh group, the whole of the Eilean Dubh group, and the lower part of the Sail Mhor group, and consisting of dolomites, limestones, and cherts, with little or no terrigenous material, the only fossils that can be shown to be due to

[3] *Geol. Mag.*, vol. x., new series, p. 126, 1883.

organisms are worm casts of the nature of *Planolites*, although the limestone and chert may have originated from the débris of the calcareous and siliceous organisms of the plankton. A noticeable feature of the Ghrudhaidh and Eilean Dubh groups is the occurrence in them of bands of brecciated dolomite on several horizons, which do not imply any break in the continuous sequence of deposits. The total thickness of this portion of the Durness dolomites and limestones, yielding no fossils beyond worm casts, amounts to 350 feet.

But in the upper part of the Sail Mhor group siliceous and calcareous organisms of a higher grade make their appearance Among the former we find the *Rhabdaria* of Billings The calcareous forms are represented by (1) gasteropods, including a single specimen of a murchisonid, and two species of a pleurotomarid (*Euconia Ramsayi* and *E Etna*) of a type occurring in the calciferous rocks of Newfoundland and Canada; (2) cephalopods, comprising two slightly bent forms with closely set septa and wide endogastric siphuncles, showing affinities with those of *Endoceras* and *Piloceras*; (3) arthropods, represented by the epitome of a large asaphoid trilobite resembling that of *Asaphus canalis* of Conrad This evidence is insufficient to determine the exact horizon of these beds, but clearly indicates that we are no longer dealing with Lower Cambrian strata The cephalopods are like those found in the Ozarkic division of Ulrich (Upper Cambrian), in North America According to Schuchert, the cephalopods with closely set septa are of Cambrian type and older than those of the Beekmantown terrane of American geologists On the other hand, the asaphoid type of trilobite is suggestive of a somewhat higher horizon

No fossils have been found in the overlying Sangomore group, about 200 feet thick, which consists mainly of granular dolomite, with bands of chert, some being oölitic, together with thin fine-grained limestones near the top

Above this horizon, at a height of over 800 feet above the top of the *Olenellus* zone, we encounter the great home of the fossils peculiar to the Durness limestone in the Balnakeil and Croisaphuill groups The former consists mostly of dark limestones, with nodules of chert, and, with a few alternations, of white limestone bands A few thin layers are charged with worm casts The overlying group is more varied, the lower part being composed of dark grey limestones full of worm casts, and with some small chert nodules arranged in lines, the middle portion, of dark granular and unfossiliferous dolomite; and the upper part, of massive sheets of fossiliferous limestone full of worm casts The total thickness of these two groups in Durness is about 550 feet

These two subdivisions have yielded over twenty genera and about one hundred species In Durness sixty-six species have been obtained from the Balnakeil group alone, fifteen of which have not as yet been found in the overlying Croisaphuill group, thus leaving fifty-one species common to both divisions The Ben Suardal limestones in Skye, which were mapped by the Geological Survey as one division, are regarded, on palæontological grounds, as the equivalents of both these groups Owing to the number of species common to both subdivisions, the fauna will be here referred to as a whole

Both siliceous and calcareous organisms are present in this fauna Among the former we find *Archæoscyphia* (Hinde), described by Billings as *Archæocyathus*, an early Cambrian coral, but shown by Hinde to be a siliceous sponge [4] The genus *Calathium* is represented by four species Other genera and species of sponges occur, so that the siliceous nodules, which are very common in both groups, may be in great part due to them In this connection it may be mentioned that Hinde obtained sponge spicules from some of the nodules Hinged brachiopods have also been collected from these beds and include *Nisusia* (*Orthisina*) *festinata*, *N grandæva*, and Camarella

But the characteristic feature of the fauna is the assemblage of calcareous mollusca comprising lamellibranchs, gasteropods, and cephalopods, showing a wide range of variation, and consequently a long ancestry The lamellibranchs, though represented only by two genera, *Euchasma* and *Eopteria* of Billings, with several intermediate forms, are of extreme interest, as they are only known to occur elsewhere in Newfoundland and Eastern Canada The gasteropods, however, furnish the largest number of species—about 48 per cent of the whole The primitive euomphalids, *Maclurea* and *Ophileta*, are most characteristic.

[4] *Quart Jour Geol Soc*, vol xlv, p 125, 1889

The former genus has a large number of species, many of which are to be found in the Beekmantown limestone of Newfoundland and Eastern North America Only one of the species (*Maclurea Peachi*) is peculiar to Durness Several species of *Ophileta* are found, some of which likewise occur in the Beekmantown limestone. Euomphalus has also been recorded, while several forms belonging to the nearly allied family of the Turbinidæ, and placed in Lindstrom's genus *Oriostoma*, are also met with in the Beekmantown limestone

Murchisonids and Pleurotomarids number twenty-seven species and show a very wide range of variation The chief subgenera of the former are *Hormotoma* and *Ectomaria*, many species of which occur with remarkable variations All the types of variation found in Durness are to be found in North America, and several of the species are common to both regions The pleurotomarids vary in a similar manner, the chief genera being *Raphistoma* and *Euconia*, and a form resembling *Hormotoma*, only with a shorter spire. Species belonging to each of these subgenera are likewise common to both areas, while some are only known from the North-West Highlands

The cephalopods are of equal interest They are also of primitive type and, at the same time, show a wide range in form The prominent feature in the straighter specimens is the great width of the laterally placed siphuncle, which is generally furnished with endocones and organic deposits The genus *Piloceras* is the most characteristic type and shows this peculiar feature best It has only been recorded from Scotland, Newfoundland, Canada, and the eastern States of North America The following additional genera are represented—viz , *Endoceras*, chiefly by siphuncles in great variety; *Actinoceras*, *Cyrtoceras*, and, doubtfully, *Orthoceras*. Several forms have been attributed to *Orthoceras* which, on re-examination, have been found to be the siphuncles of other genera, resembling American types described by Hall and Whitfield

The whorled nautiloids provisionally classed with the genus *Trocholites* of Conrad are represented by several distinct forms as yet unnamed

The trilobites are of rare occurrence in these two groups of dolomite and limestone They are fragmentary and poorly preserved This is doubtless one of the disappointing features connected with this remarkable assemblage of organic remains, for the presence of a zonal form would have helped to define the horizon of these beds Only one species, *Bathyurus Nero* (Billings) has been identified, which also occurs in the Beekmantown limestone of Newfoundland The other trilobite remains, though poorly preserved, leave a Cambrian facies characteristic of North America

In connection with this fauna certain features have been observed which throw some light on the absence of calcareous organisms from thick zones of the Durness dolomite and limestone In my detailed description of the palæontology of the Cambrian rocks of the North-West Highlands in the *Geological Survey Memoir* I stated that 'in most cases the septa and walls of chambered shells have been wholly or in part dissolved away, so as to leave only the more massive structures of the siphuncles, and worm castings are often found within the chambers where the septa have been preserved These features seem to indicate that the accumulation of the calcareous mud in which the fossils were embedded was so slow that there was time for the solution of part of an organism before the whole of it was covered up '[5] There is good reason to believe that many organisms wholly disappeared by this process, so that it is reasonable to conclude that the fossils obtained from the Durness dolomites cannot be regarded as furnishing a complete life-history of the forms that originally existed in that sequence of deposits Attention has already been called to the fact that beneath the two subdivisions now under consideration there are groups of dolomite and limestone which so far have yielded no organic remains beyond worm castings And even in the important Croisaphuill group, with its fossiliferous zones, there are thick groups of dolomite which have furnished no calcareous organic remains Obviously the palæontological record in this instance is glaringly incomplete, for we have no reason to suppose that the life of the time flourished in some of the calcareous zones and not in others

The highest subdivision of the Durness limestone, measuring about 150 feet

[5] 'Geological Structure of the North-West Highlands,' *Geol Sur Mem*, 1907, p. 380.

in thickness (Durine group), has yielded two species of *Hormotoma*—viz., *H. gracilis* and *H. gracillima*—both of which occur in the two underlying groups. *H. gracilis* occurs in the Beekmantown, the Chazy, and the Trenton limestones of America.

Before assigning any stratigraphical horizons to the fauna of the Durness dolomites, it is desirable, owing to the American facies of the fossils, to recapitulate the evidence bearing upon the life of Cambrian time in North America. But the Cambrian life-history of Scotland would be incomplete without a brief reference to the recent discovery of fossils along the eastern border of the Highlands.

In 1911 Dr. Campbell announced in the *Geological Magazine* that fossils had been found in the Highland border series north of Stonehaven, and, during this year, Dr. Jehu made a similar discovery in rocks belonging to this series near Aberfoyle. Papers on these subjects will be communicated to this Section. For my present purpose it will be sufficient to indicate the nature of the fossils and the lithological characters of the rocks containing them.

The Highland border series north of Stonehaven and near Aberfoyle includes sheared igneous rocks, both lavaform and intrusive, with black shales, cherts, and jaspers. North of Stonehaven the fossils occur in thin, dark, flinty pyritous shale, while at Aberfoyle they have been found in shaly films at the edge of the chert bands. Several years ago radiolaria were detected in the cherts between Aberfoyle and Loch Lomond. From time to time these Highland border rocks have been carefully searched for fossils, but until recently with little success, owing to the intense movement to which they have been subjected, resulting in marked flaser structure in all except the most resistant bands.

The fossils consist chiefly of horny, hingeless brachiopods, phyllocarid crustacea, worm tubes, and the jaws and chetæ of annelids. The genera of brachiopods comprise *Lingulella, Obolus, Obolella, Acrotreta*, and *Linarssonia*. The association of these brachiopods with phyllocarid crustaceans resembling *Hymenocaris* and *Lingulocaris* is suggestive of an Upper Cambrian horizon—an inference which is supported by the absence of graptolites.

In the published Geological Survey maps these Highland border rocks are queried as of Lower Silurian age. This correlation was based partly on their resemblance to the Arenig volcanic rocks and radiolarian cherts of the Southern Uplands, and partly because, as shown by Mr. Barrow, they are overlain by an unconformable group of sediments, termed by him the Margie series. The cherts, the green schists, and the Margie series have shared in a common system of folding, and are unconformably surmounted by Downtonian strata near Stonehaven. Though the original correlation may not be strictly correct, it is probable, in my opinion, that representatives of both the Arenig and Upper Cambrian formations may occur in the Highland border series, and, further, that Upper Cambrian strata may yet be found in the Girvan area, as originally suggested by Professor Lapworth in correspondence with Dr. Horne.

The Cambrian Fauna of North America.

The classification of the Cambrian fauna found in North America is based on the researches of a band of distinguished palæontologists, comprising among the older investigators Billings, Hall, and Whitfield, and among modern workers Walcott, Ulrich, Schuchert, Brainerd, Seely, Ruedemann, Matthew, Clarke, and Grabau. Prominent among these investigators stands Dr. Walcott, alike for his original and exhaustive contributions to this branch of inquiry and for his complete mastery of the sequence and distribution of life in Cambrian time in North America. Indeed, geologists all over the world owe him a deep debt of gratitude for the services which he has rendered to Cambrian palæontology.

Throughout the greater part of Cambrian time there existed in North America two distinct life provinces. The eastern one ran along the Atlantic coast from the north of Newfoundland to a point south of New York, extending only a short distance inland, with a faunal facies resembling that of North-West Europe, exclusive of the North-West Highlands of Scotland. The western province lay to the north-west of that just described, and ranged from Northern Newfoundland, south-westwards to Central North America and the Pacific Ocean. On the east side of the Rocky Mountains it swept northwards to British

Columbia, perhaps as far as the Arctic Ocean. The remarkable feature of the life of the western province is its essentially American facies.

Geologists are familiar with the triple classification of the Cambrian system by means of the trilobites in North America, as in Europe. The Lower Cambrian division represents the *Olenellus* epoch of Walcott, characterised by some form of Olenellid, or, to use the name now given to the family by that investigator, the *Mesonacidæ*. The western life-province contains the true *Olenellus* of which *O. Thompsoni* is the type. The strata yielding this fauna extend over such a wide area of North America that within this same province we find a western and an eastern facies. The western facies is found in Nevada and California, where *Olenellus* is represented by such specific forms as *O. Gilberti* and *O. Freemonti*. But it is noteworthy that these forms occur near the top of the Lower Cambrian series, and are soon followed by *Zacanthoides* and *Crepicephalus*, trilobites of middle Cambrian affinities. Towards the lower part of the sequence of deposits, which there consist mainly of limestone, and extend downwards for a distance of over 4,000 feet beneath the beds containing the true *Olenellus*, Walcott found specimens of *Holmia Rowei* and *Nevadia Weeksi*. The latter form is regarded by him as the most primitive of all the *Mesonacidæ* yet known. Near the base the limestones have yielded the primitive corals *Archæocyathus* and *Ethmophyllum*, and the brachiopods *Micktwitzia* and *Trematobolus*. The other forms found on this horizon belong to the following genera: (trilobites) *Protypus* and *Microdiscus*, (brachiopods) *Kutorgina*, *Swantonia*, *Nisusia*, *Billingsella*, and (tubicolar annelids) *Hyolithellus* and *Salterella*. The eastern facies of the western life-province is best known from the region of Georgia, in Vermont. It is the home of the type species of *Olenellus* (*O. Thompsoni*). It is associated with *Mesonacis vermontana*, which has now given the name to the whole family, with *Elliptocephalus asaphoides*, one of the earliest known trilobites of the family, and with other forms such as *Bathynotus*, *Holopygia*, *Protypus*, and *Microdiscus*. The tubicolar worms are represented by *Hyolithellus* and *Salterella*, the brachiopods by *Nisusia*, *Swantonia*, *Kutorgina cingulata*, and *Paterina labradorica*. There can be no doubt that the assemblage of organic remains found in this Georgian terrane is merely the counterpart of that found in the *Olenellus* zone of the North-West Highlands.

Proceeding now to the eastern life-province, we find that the Lower Cambrian rocks are characterised by the trilobite genus *Callavia*, belonging to the family of the *Mesonacidæ*, and bearing a close resemblance both to *Holmia* and *Nevadia*. In Southern Newfoundland two species of *Callavia* occur, of which *C. Broggeri* is the type. It is accompanied by *Microdiscus*, *Hyolithellus*, *Paterina labradorica*, and *Helenia bella*. In New Brunswick the *Protolenus* fauna, with *Protolenus* as the characteristic trilobite, probably represents the upper part of the *Olenellus* zone. In this connection the recent discovery of the *Protolenus* fauna by Mr. Cobbold, in Shropshire, in strata associated with *Callavia*, and overlain by beds yielding *Paradoxides*, is of special importance, as it shows the close relation between the Lower Cambrian fauna of Wales and that of the Atlantic or eastern province of North America.[6]

The Middle Cambrian division of the western life-province is characterised chiefly by the trilobite genus *Olenoides*; indeed, the western part of it is the home of *Olenoides* and the large tailed trilobites. The characteristic genera of this group to be found in that region are *Kootenia*, *Zacanthoides*, *Bathyuriscus*, *Asaphiscus*, *Neolenus*, *Dorypygella*, *Dorypyge*, *Damesella*, and *Ogygopsis*.

In this region the Middle Cambrian limestones and shales occurring on Mount Stephen, in British Columbia, have yielded a magnificent series of trilobites, eurypterids, limuloids, crustacea ranging from congeners of the brine shrimps to phyllocarid nebalids, annelids belonging to most of the still extant families, holothurians, medusæ, and other organic remains. For the most part many of these forms are so fragile that only their tracks remain as indications of their existence in palæozoic deposits. Not till we reach the Solenhofen slates in Jurassic time do we find similar favourable conditions for the entombment and preservation of their highly modified successors. The remarkable evidence bearing on the evolution of groups of organisms furnished by this assemblage of fossils from Mount Stephen has been admirably described and illustrated by

[6] *Quart. Jour. Geol. Soc.*, vol. lxvii., p. 296, 1911.

Walcott in his series of papers published in the Smithsonian Miscellaneous Collections.

In the New Brunswick portion of the eastern or Atlantic life-province the strata yielding *Paradoxides* follow those bearing the *Protolenus* fauna Six species of Paradoxides have been obtained from this horizon, including *P. davidis*, together with the following genera · *Agnostus, Agranlos, Liostracus, Conocoryphe*, and *Ctenicephalus* Schuchert points out that this fauna is 'closely allied to the *Paradoxides* faunas of Wales and Sweden, but less so with that of Bohemia.'[7]

In Southern Newfoundland Walcott showed that the base of the Middle Cambrian division is marked in Manuel's Brook by a conglomerate containing fossils of the lower or Georgian terrane, thus indicating elevation and erosion of the Lower Cambrian rocks Higher up the strata yielded *Paradoxides davidis* and *P bennetti*.

Important evidence pointing to the conclusion that the *Paradoxides* fauna of the eastern or Atlantic province encroached to some extent on the eastern part of the western life-province has been obtained by Walcott at St Albans, Vermont But the suggestion has been made by Schuchert that their present position is there due to north-westerly thrusting[8]

It should be borne in mind that in Middle Cambrian time the eastern and western parts of the western life-province were evidently separated from each other by a land barrier, owing to crustal movement, which was probably connected with the elevation of the Lower Cambrian rocks in the region where they were subjected to erosion

In the upper division of the Cambrian system in North America there is a marked change in the fauna Its characteristic features are thus clearly summarised by Schuchert. 'In a general way it may be said that the Ozarkic period of Ulrich (Upper Cambrian) begins with the trilobite genus *Dikelocephalus* and the first distinct molluscan fauna . . . The trilobites and inarticulate brachiopods (greatly reduced in species) are still Cambrian in aspect, while the new faunal feature consists in a rapid evolution, in form and size, of the coiled gasteropods, and of both straight and coiled cephalopods The latter are distinguished from those of subsequent periods by the exceedingly close arrangement of the septa.'[9]

The distinctive trilobite genus of the Upper Cambrian strata of the western life-province is *Dikelocephalus*, where it is associated with an American facies of fossils The eastern or Atlantic province is characterised by Olenids, though *Dikelocephalus* also occurs, and by typical European forms In Minnesota and Wisconsin, where the strata consist of sandstones, dolomites, and shales, two species of *Dikelocephalus* have been obtained, together with other genera of trilobites such as *Agnostus* and *Illænurus*, the limuloid *Aglaspis*, and the gasteropods *Holopea, Ophileta*, and *Raphistoma*

In certain areas this period is characterised by a great succession of calcareous deposits, comprising parts of the Shenandoah limestone and Kittatinny dolomite in New Jersey, portions of the Knox dolomite in Tennessee, and of the dolomite and limestone in Oklahoma In some of these localities, at least, the lower portions of this calcareous series are grouped with the Upper Cambrian sediments, while the upper parts are classed with Lower Silurian or Ordovician strata. The researches of American palæontologists have shown that in certain areas there is a mixed Cambrian and Ordovician fauna in some of the beds, as in the Tremadoc rocks of Wales This commingling of faunas is exemplified in the case of the Beekmantown limestone, which is grouped with the Ordovician (Lower Silurian) rocks by most American geologists Ulrich and Schuchert, on the other hand, regard it as a formation (the Canadic) distinct from the overlying Ordovician system

The type areas of the Beekmantown limestone are Lake Champlain, the Mingan Islands, and Newfoundland, where the strata consist mainly of a succession of limestones and dolomites over 1,000 feet thick. The fossils are chiefly molluscan, comprising lamellibranchs, gasteropods, and cephalopods The lamellibranchs are represented, among others, by the genera *Euchasma*

[7] *Bull Geol Soc of Amer*, vol xx. (1910), p 522 [8] *Ibid*
[9] *Op cit*, p. 524.

and *Eopteria*, the gasteropods, by *Ophileta, Maclurea, Euomphalus, Holopea, Hormotoma, Ectomaria, Murchisonia, Lophospira, Euconia, Raphistoma, Helicotoma*, the cephalopods, by *Orthoceras, Cyrtoceras, Gomphoceras, Piloceras, Trocholites* Of the foregoing genera many of the species are common to this region and the North-West Highlands of Scotland

The trilobites associated with this fauna comprise the genera *Dikelocephalus, Bathyurus, Asaphus, Harpes*, and *Nileus*

In Northern Newfoundland, in zones F to N of Billings, this fauna, with localised species, is found in great development, in limestones and dolomites resembling those of Durness Its upper limit is there clearly defined, for the limestones and dolomites are overlain by dark shales containing graptolites of undoubted Arenig age

A careful comparison of the faunas of the Durness and Beekmantown limestones shows that the assemblage of fossils in the Balnakiel and Croisaphuill groups of Durness is practically identical with that in the zones F to N of Billings, as developed in Newfoundland These groups must therefore be older than the Arenig rocks of Wales, and must represent at least the Welsh Tremadoc strata, if not part of the Lingula Flags, both of which, according to the English classification, are grouped with the Cambrian system

But even in the purely European province of North America, in New Brunswick, where the Beekmantown calcareous fauna is entirely absent, and where the faunal sequence and type of sedimentation are almost identical with those of North Wales, the basal Ordovician or Lower Silurian rocks of American geologists include the *Peltura scarabæoides* and the *Parabolina spinulosa* zones, which, in Wales, are classed with the Lingula Flags It is obvious, therefore, that the boundary-line between the Cambrian and Ordovician (Lower Silurian) systems is not drawn at the same stratigraphical horizon by American and British geologists In fixing the age of the Durness dolomites and limestones the English classification has been adopted

The palæontological evidence now adduced regarding the relation of the Cambrian fauna of the North-West Highlands to that of North America leads to the following conclusions —

1 The Lower Cambrian fauna of the North-West Highlands, distinguished by the genus *Olenellus* and its associates, is almost identical in character with that of the Georgian terrane of the western life-province of North America, and essentially different from the Lower Cambrian fauna of the rest of Europe

2 No forms characteristic of the Middle Cambrian division, either of Europe or North America, have as yet been found in the North-West Highlands, but this division may be represented by the unfossiliferous dolomites and limestones of the Ghrudhaidh, Eilean Dubh, and the lower Sail Mhor groups

3 The fossiliferous bands of the Sail Mhor group may be the equivalents of the lower part of the Upper Cambrian formation

4 The Balnakeil and Croisaphuill groups of the Durness dolomites and limestones contain a typical development of the molluscan fauna of the Beekmantown limestone, belonging to the western life-province of North America As the Beekmantown limestone is succeeded by shales, with Arenig graptolites, it follows, in accordance with British classification, that these groups must be of Upper Cambrian age

5 The highest subdivision of the Durness limestone (Durine) has not yielded fossils of zonal value, and the members of this group are not overlain in normal sequence by graptolite bearing shale or other sediments

Cambrian Palæogeography between North America and North-West Europe

In attempting to restore in outline the distribution of land and sea in Cambrian time between North America and North-West Europe reference must be made to various investigators whose researches in palæogeography are more or less familiar to geologists Among these may be mentioned Suess, Dana, De Lapparent, Frech, Walcott, Ulrich, Schuchert, Bailey Willis, Grabau, Hull, and Jukes Browne. The views now presented seem to me to be reasonable inferences from the palæontological evidence set forth in this address

In the North-West Highlands there is still a remnant of the old land surface upon which the Torridonian sediments were laid down There is conclusive

evidence that the pre-Torridonian land was one of high relief. As the Torridonian sediments form part of a continental deposit it may be inferred that the Archæan rocks had a great extension in a north-westerly direction. The increasing coarseness of the deposits towards the north-west suggests that the land may have become more elevated in that direction. At any rate, the pile of Torridonian sediments points to a subsidence of the region towards the south-east, and probably to a correlative movement of elevation towards the north-west.

The sparagmite of Scandinavia is an arkose resembling the dominant type of the Torridon sandstone, is of the same general age, and has evidently been derived from similar sources in the Scandinavian shield. In eastern North America coarse sedimentary deposits form part of the newer Algonkian rocks, which are still to be found rising from underneath the Cambrian strata in the region of the Great Lakes. These materials were obtained from the great Canadian shield, which must have formed a large continental area during their deposition.

It is reasonable to infer that these isolated relics of old land surfaces were united in pre-Torridonian time, thus forming a continuous belt from Scandinavia to North America. During the period which elapsed between the deposition of the Torridon sandstone and the basement members of the Cambrian system a geosyncline was established which gave rise to a submarine trough, trending in an east-north east and west-south-west direction, both in the British and North American areas. In the latter region it extends from Newfoundland to Alabama, its south-eastern limit being defined by the old land surface of Appalachia. The extension of this Appalachian land area in a north-east direction beyond the limits of Nova Scotia and Newfoundland was postulated by Dana and other American writers. This geosyncline remained a line of weakness throughout palæozoic time, both in Britain and North America, which resulted in the Caledonian system of folding in Britain, and in the Taconic, Appalachian, and Pennsylvanian systems in North America. Hence it is manifest that the original shore-lines of this trough are now much nearer each other than they were in Cambrian time.

The Cambrian rocks of the North-West Highlands were laid down along the north-west side of this trough during a period of subsidence, for the great succession of Durness dolomite and limestone, with little or no terrigenous material, is superimposed on the coarser sediments of that formation. On the other hand, the Cambrian strata of Wales seem to have been deposited along the southern limit of this marine depression. The Archæan rocks that now constitute the central plateau of France may have formed part of its southern boundary. The extension of this land area towards the north-east may have given rise to the barrier that separated the Baltic life-province from that of Bohemia, Sardinia, and Spain. In my opinion, this southern land area in Western Europe was continuous across the Atlantic with Appalachia. For the life sequence found in the Cambrian rocks of New Brunswick is practically identical with that of Wales and the Baltic provinces, thus showing that there must have been continuous intercourse between these areas. Along this shore-line the migration of forms seems to have been from Europe towards America. On the other hand, along the northern shore the tide of migration seems to have advanced from America towards the North-West Highlands. The question naturally arises, what cause prevented the migration of the forms from one shore of this trough to the other? American geologists are of opinion that this is probably due to the existence of land barriers, but, in my opinion, it can be more satisfactorily accounted for by clear and open sea, aided by currents.

The south-western extremity of the American trough in Lower Cambrian time opened out into the Mississippian sea, which was connected with the Pacific Ocean, and stretched northwards towards the Arctic regions. Reference has already been made to Walcott's discovery in Nevada of the primitive trilobite *Nevadia Weeksi*, from which he derives both branches of the *Mesonacidæ*, one branch linking *Nevadia*, through *Callavia*, *Holmia*, and *Wanneria*, with *Paradoxides*, the other connecting *Nevadia* with *Olenellus*, through *Mesonacis*, *Elliptocephalus* and *Pædumias*.

In Nevada the genus *Holmia*, as already shown, is associated with the primitive type *Nevadia*. *Wanneria* is found in Nevada, in Alabama, and in Pennsylvania, thus showing that this genus is common to the Mississippian sea and to

the long trough north east of Alabama. *Mesonacis* has been obtained in the submarine depression at Lake Champlain, at Bonne Bay, Newfoundland, and at the north side of the Straits of Belle Isle. *Elliptocephalus* has been recorded from the New York State. *Olenellus* has been found in Nevada, in Vermont, and in the North-West Highlands. All the genera now referred to may have migrated along the north-western shore of this trough.

As regards the distribution of the genus *Callavia*, this form has been met with in Maine, in Newfoundland, and in derived pebbles in a conglomerate in Quebec. Two species have been recorded in Shropshire. These forms probably moved along the southern shore of this sea from Wales to North America.

Reference has already been made to the fact that, in the interval between Lower and Middle Cambrian time, in certain areas in North America the Lower Cambrian rocks were locally elevated and subjected to erosion. During this interval the southern end of the trough seems to have had no connection with the Mississippian sea, for in Middle Cambrian time, as already indicated, the *Paradoxides* fauna is found in the trough on the east side of North America, whereas on the west side it is represented by the *Olenoides* fauna.

In Upper Cambrian time a great transgression of the sea towards the north supervened. The *Dikelocephalus* fauna is found on both sides of America, thus showing that the previous land barrier had been submerged. While this genus occurs in Wales and the Baltic provinces, it has not as yet been recorded from the North-West Highlands, but I quite expect that this discovery may be made at some future time.

Along the northern side of the American trough clear water conditions prevailed, owing to the northward recession of the shore-line, which led to the accumulation of a great succession of calcareous deposits, including the Beekmantown limestone, to which reference has already been made. Schuchert, as already stated, has pointed out that, in the lower part of the Ozarkic (Upper Cambrian) system, in Minnesota and Wisconsin, the gasteropod genera, *Holopea*, *Ophileta*, and *Raphistoma*, are associated with two species of *Dikelocephalus*. This molluscan fauna is evidently the precursor of that of the Beekmantown limestone. It was probably from this central region of America that the calcareous fauna of Beekmantown migrated to the submarine trough in the typical Champlain region, and through Newfoundland to the North-West Highlands of Scotland.

The section at St. John, New Brunswick, where the Baltic and Welsh types of the *Olenus* fauna occur, shows that the southern shore-line of the trough must then have occupied much the same relative position as in Lower and Middle Cambrian time. In the same region the strata containing this fauna, with *Peltura scarabaeoides*, and *Dictyonema flabelliforme* are overlain by dark shales with Arenig graptolites. These graptolite-bearing terrigenous deposits eventually extended across the trough northwards, till, in Newfoundland, they came to rest on the Beekmantown limestones.

In the Lake Champlain region, in the Chazy limestone, which there immediately succeeds the Beekmantown limestone without the intervention of the Arenig graptolite shale, there is a survival of the Beekmantown molluscan fauna with only such slight modifications as to indicate genetic descent. In the same trough the descendants of this fauna are to be found in the Trenton limestone.

In this connection it is worthy of note that the molluscan fauna and the corals of the Stinchar and Craighead limestones of Upper Llandeilo age in the Girvan district of the Southern Uplands have an American facies, as first suggested by Nicholson. The appearance of American types in these limestones may be accounted for in the following manner. Attention has already been called to the divergent types of sedimentation presented by the Upper Cambrian strata of the North-West Highlands, and of the South East Highlands, at Stonehaven and Aberfoyle. In the former case there is a continuous sequence of dolomites and limestones, while in the latter we find a group, comprising radiolarian cherts and black shales, associated with pillowy spilitic lavas and intrusive igneous rocks, indicating conditions of deposition at or near the limit of sedimentation. But, notwithstanding the different types of sedimentation and the divergent faunas in the two areas, I believe that during the Upper Cambrian period, and probably for some time thereafter, continuous sea

extended from the North-West Highlands to beyond the Eastern Highland border The Upper Cambrian terrigenous sediments which we now find at Stonehaven and Aberfoyle must have been derived from land to the south In Llandeilo time the Arenig and Lower Llandeilo rocks of the Girvan area were elevated and subjected to extensive denudation On this highly eroded platform, as first proved by Professor Lapworth, coarse conglomerates, composed of the underlying materials, were laid down in association with the Stinchar and Craighead limestones In my opinion the appearance of the American forms in these limestones is connected with the movement that produced this unconformability in the Girvan area This local elevation was probably associated in some form with the great crustal movements that culminated in the overthrusts of the North-West Highlands and caused the intense folding and flaser structure of the rocks along the Highland border By these movements shore-lines may have been established between the north side of the old Palæozoic sea and the Girvan area, which permitted the southern migration of the American forms

Note —Since writing the above my attention has been directed to the recent work of Bassler on 'The Early Palæozoic Bryozoa of the Baltic Provinces,' published by the Smithsonian Institution in 1911 In his introduction the author has shown that the Ordovician (Lower Silurian) and Gothlandian (Upper Silurian) rocks of the Baltic Provinces contain a large percentage of bryozoan species, in common with the Black River, Trenton, and Niagara limestones of the same relative age in Eastern North America This fact suggests that during Lower and Upper Silurian time the old lines of migration were still open, and that the Bryozoa, being of clear-water habit, were able to cross the old trough from side to side

The following Papers and Reports were then read —

1 *On the Geology of the County around Dundee and St Andrews* *By* Professor T J JEHU, *M A* , *M D*

2 *A Mull Problem The Great Tertiary Breccia* *By* E B BAILEY

[With the permission of the Director of the Geological Survey]

There is in eastern Mull a great breccia formation, with, in places, several intercalated rhyolite lavas The breccia consists for the most part of an unbedded assemblage of blunted blocks and fragments of gneiss, granophyre, gabbro, and basalt, often associated with rhyolitic débris, for which latter a truly volcanic origin can be readily admitted The problem is whether the non-rhyolitic material of the breccia has been derived through explosion or erosion If the former alternative is adopted, many of the breccia outcrops must be regarded as marking the sites of volcanic vents, since in several cases the boundaries of the breccia are frankly transgressive At the present time it is considered that the evidence favours an alternative view, that the breccia is an unconformable formation later than the basalt lavas of Mull, and that its transgressive relations are due to erosion which preceded and accompanied its formation The basalt lavas of Mull have been violently folded into a series of anticlines and synclines, and it is in one of these synclines that the main outcrop of breccia in eastern Mull is preserved, with every appearance, moreover, of approximate conformity to the surrounding basalts Here it is difficult to escape the conclusion that the breccia is a thick layer overlying the basalts and folded with them Alongside of the syncline is an abrupt anticline, in which are exposed all the rocks commonly recognisable as fragments in the breccia The anticline has a core of gneiss, flanked locally by upturned mesozoic sediments, and these by steeply dipping basalt lavas, intruded, chiefly into the gneiss, are granophyre and gabbro Patches of breccia, distributed without reference to geological structure, occur in this anticlinal region, and rest upon or against all the rocks mentioned above Although no positive

conclusion can be drawn, it is suggested that the breccia has in large measure resulted from erosion, which operated during the period of upheaval of this and neighbouring anticlinal ridges

3 *The Silurian Inlier of Usk* By C I GARDINER, *M A, F G S*

The Usk Inlier is roughly oval in shape, measuring about eight miles and a half from N to S and four miles from E to W It is crossed by an important E and W fault, which divides it into two nearly equal parts The southern half is composed of two anticlines separated by a fault The axes of these folds run roughly north and south, and dip southwards The western anticline is the larger of the two, and shows Wenlock Shales and Limestone and Ludlow beds, these are all very fossiliferous

The anticline has been much broken by faulting, and the limestone is now in twelve separate parts Careful observations of the dips prove faulting to be a satisfactory explanation of this separation The Silurians are separated from the Old Red Sandstone to the west, from Littlemill to Trostra, by a fault, but from Trostra to Llandegveth and Graigwith the basement bed of the Old Red Sandstone, a yellow quartzose sandstone, rests with apparent conformity on the Ludlow beds The eastern anticline is thinner than the western one Its lowest bed seen is the Wenlock Limestone of Cwm Dowlais, this being covered by Ludlow beds, which run south through Llangibby Park A fault line separates these Ludlows from the Old Red Sandstone to the east The Wenlock Shale is a brown sandy shale where its lowest beds are seen in the railway cuttings near Bryn, and it becomes more sandy in its higher parts, a definite sandstone occurring close to its summit The Wenlock Limestone has about twelve feet of massive limestone at its base, largely formed of crinoid fragments, and, above this, irregularly bedded limestone separated by thin shaly partings Corals are scarce, brachiopods and trilobites common The Ludlow beds are, for the most part, brown sandy shales, with calcareous nodules or thin calcareous layers, but towards their summit they pass up into sandstones The northern half of the Inlier is far less simple than the southern in its structure, and is more concealed by drift Its western boundary is everywhere obscured, but Ludlow beds are seen here and there dipping towards the Old Red Sandstone not far off the boundary The central part is composed of Wenlock Shale, and the eastern margin is composed of Ludlow beds dipping eastwards and faulted against the Old Red Sandstone The Wenlock Limestone is not met with in this northern half of the Inlier The simpest explanation of these facts is that the Wenlock Shale is faulted against the Ludlow beds on both sides As the Aymestry Limestone is absent from the district, it seems impossible to separate the Ludlow beds into an upper and a lower division, but fossils have been carefully collected in order to see if any horizons can be fixed The main boundary faults are crossed at several spots by minor east and west faults, which cause small lateral displacements

---

4 *Preliminary Note on a Buried River Channel near Peterborough* By Rev A IRVING, *D Sc, B A*

Attention was drawn to the existence of a pre-glacial river channel (250 yards wide at Fletton) So far as the evidence has been investigated in the field the channel appears to have been buried under glacial deposits, across which the River Nene cuts its upper course The general trend of the channel points to a possible connection (in pre-glacial times) with the upper part of the Trent basin in one direction, and with the Thames basin (through the buried valleys of the Cam and the Stort) [1] in the other; and, so far as the examination has gone, this inference is borne out by the nature of the detritus which fills the ancient channel The writer hopes to carry out a more complete examination of the ground during the next few weeks Meanwhile the postulated capture of the Lower Trent by the Humber can be fairly referred to glacial damming co operating with differential movements of the crust, the Boulder Clay having

[1] A Irving, *Brit Assoc Reports*, Sheffield, 1910, p 616

been observed by Dr J J Harris Teall and the writer to have a thickness of ninety feet when the Midland Line was in process of construction from Melton Mowbray to Nottingham The banks of the ancient channel through the Oxford Clay shales are clearly shown in open sections at the recently extended brick-works at Fletton, to the manager of which, Mr A Adams, the writer is indebted for facilities in the investigation

5 *Report on the Composition and Origin of the Crystalline Rocks of Anglesey* —See Reports, p 125

6 *Report on the Occurrence of the Bembridge Limestone at Creechbarrow Hill* —See Reports, p 129

FRIDAY, SEPTEMBER 6

The following Papers and Reports were read —

The Discovery of Fossils in the Jasper and Green Schist Series of the Highland Border at Craigeven Bay, Stonehaven By ROBERT CAMPBELL, *M A , D Sc*

Between Craigeven Bay and Garron Point occurs a series of crushed spilitic lavas with intercalated black shales, jaspers, and cherts In their lithological characters these resemble closely the green igneous rocks and associated sediments which appear at intervals along the line of the Highland Boundary fault, and which are shown on the Geological Survey maps as of (?) Arenig age In August 1909, on the occasion of a visit to Craigeven Bay in company with Dr B N Peach and Dr W T Gordon, we succeeded in finding in the black shales several fossils, including a linguloid shell and a bivalve phyllocarid crustacean The assistance of Mr D Tait, of H M Geological Survey, was obtained in making a detailed search in the fossiliferous beds Dr Peach, to whom the fossils were submitted for determination, has identified the following forms *Lingulella, Obolella, Acrotreta, Linnarssonia,* and *Siphonotreta*, a bivalve phyllocarid allied to *Caryocaris* and *Lingulocaris*, and cases of a tubicolar worm The above genera are most commonly found in the lowest division of the Lower Silurian (Ordovician) system and in the Upper Cambrian Dr Peach, while admitting that the exact horizon of the fossils is still a matter of doubt, suggests that, since graptolites are absent, they are more likely to belong to the Upper Cambrian than to the Ordovician Whatever may be the ultimate decision as to their stratigraphical horizon the discovery of the above fossils leaves very little doubt that the boundary fault series is *not* pre-Cambrian

The (?) Upper Cambrian rocks at Craigeven Bay are separated from the Dalradian Schists by a reversed fault, and are overlain unconformably by Upper Silurian (Downtonian) strata

2 *The Downtonian and Old Red Sandstone of Kincardineshire* *By* ROBERT CAMPBELL, *M A , D Sc.*

I.—DOWNTONIAN

A thickness of nearly 3,000 feet of vertical or highly inclined strata, formerly included with the Lower Old Red Sandstone, but now regarded as of Downtonian age, intervenes between Craigeven Bay and Stonehaven Harbour Three groups of beds in this succession may be particularly noted .—

1 At the base of the series there is a thickness of about 200 feet of breccias

interbedded with fine red mudstones and made up mainly of fragments of the underlying (?) Upper Cambrian rocks. The basement breccias rest unconformably on the (?) Cambrian The unconformable junction, which is well seen on the north side of the headland at Ruthery Head, was formerly regarded as a line of faulting

2 About 20 yards east of Cowie Harbour there occurs a thick belt of grey and greenish mudstones and shales which yield *Dictyocaris* in abundance From this horizon have been obtained also *Ceratiocaris*, *Archidesmus*, sp , and a new genus of Myriopod; (?) larval form of insect, *Eurypterus*, sp. nov ; fragments of scorpion, plant fragments and worm-tracks Further, a thin bed of reddish sandy mudstone underlying the above series has yielded numerous plates of a new *Cyathaspis*

3 About 60 feet below the *Dictyocaris* horizon there is a thickness of about 40 feet of volcanic conglomerates and tuffs, the presence of which implies that the volcanic activity, which was so marked a feature in the history of this area during the Lower Old Red Sandstone period, had already been initiated in Downtonian times

Neither *Dictyocaris* nor *Ceratiocaris* has been found elsewhere in rocks younger than Upper Silurian, and, apart from the occurrence of tuffs, the lithological characters of the above succession recall at once the typical Downtonian rocks of the south of Scotland The highest beds of the Downtonian pass conformably up into the micaceous sandstone and conglomerates of Stonehaven Harbour, which may be considered as the base of the Lower Old Red Sandstone

II —Old Red Sandstone

(*a*) *Lower* —The Lower Old Red Sandstone series consists of a great thickness of coarse conglomerates and sandstones with intercalated lavas and tuffs. Palæontological evidence is everywhere meagre, but the recognition of a number of well-marked volcanic zones has been of value in elucidating the structure of the area The lavas include dacite, hornblende-biotite andesites, augite andesites, hypersthene andesites, hypersthene basalts, and olivine basalts The tuffs are all acid in character Minor intrusions of presumably Old Red Sandstone age occur in the form of dykes and thin sills of quartz porphyry, biotite porphyry, dolerite, and lamprophyre The distribution of the lavas indicates that the centres of eruption lay along two lines- one to the east of the present coast-line, the other over the area of Dalradian Schists to the north of the Highland Boundary fault

The coarse conglomerates, which build up a great part of the succession, fall readily into two groups (1) those in which boulders of quartzites or other ' Highland ' rocks predominate, (2) those which are made up almost exclusively of volcanic rocks—volcanic conglomerates Two points of particular interest may be noted in the former group—the occurrence of boulders of the ' Haggis rock ' type of greywacké, and the abundance of boulders of the 'newer' granites, which have been collected even from the lowest conglomerates The distribution of the volcanic conglomerates points clearly to the denudation of a thick series of rhyolites and acid andesites which must have extended far to the north of the Highland fault

The chief structural feature of the Lower Old Red Sandstone area is a continuation of the well-known synclinal fold of Strathmore In Kincardineshire, however, in the district to the west of Elfhill, there intervenes between the syncline and the Highland fault a steep-limbed anticline, pitching out to the south-west The southern limb of the syncline is traversed by numerous powerful dip faults

(*b*) *Upper* —The Upper Old Red Sandstone occupies a small area on the coast in the neighbourhood of St Cyrus Although no fossils have been recorded, the lithological evidence—and particularly the occurrence of characteristic cornstones —leaves no room for doubt that here we are dealing with an outlier of the more extensive tract of Upper Old Red Sandstone of Arbroath In Kincardineshire the Upper Old Red Sandstone is everywhere faulted against the Lower.

3. *Note on the Fish-remains collected by Messrs. R. Campbell, W. T. Gordon, and B. N. Peach in Palæozoic Strata at Cowie, Stonehaven.* *By* R. H. Traquair, *M.D., LL.D., F.R.S.*

The fish remains from Cowie, Stonehaven, consist of :—

1. Small scutes which are about three times as long as they are broad, slightly convex on one side and correspondingly concave on the other, and apparently pointed at both ends. They seem to me to be referable to the category of Cephalaspidian scutes, only the external ornament, where visible, consists of longitudinal and slightly wavy striæ in place of tubercles. That the species to which they belong is as yet unnamed and undescribed is pretty certain, but the advent of additional material is necessary before proceeding further in that direction.

2. Several fragments of thin minutely tuberculated plates, which may also be Cephalaspidian, though their nature, indeed, is still problematical.

3. Several specimens of a beautiful *Cyathaspis*, which I herewith dedicate to Dr. R. Campbell, and of which I give a brief diagnosis.

Cyathaspis Campbelli (Traquair).—Shield, ovoid, concave, shallow, broadest part situated behind the point of greatest expanse, covered with stout ridges running in a longitudinal direction, but also tending to converge a little anteriorly and posteriorly. These ridges are also constantly interrupted, so as to give almost a tubercular appearance, the tubercles being comparatively distantly placed, much compressed, and crenulated.

---

4. *Discovery of Fossils in the Boundary Fault Series, near Aberfoyle.* *By* T. J. Jehu, *M.A., M.D.*

This Series is well exposed between Loch Lomond and Callander, forming a narrow belt separated by a reversed fault from the Lower Old Red Sandstone on the S.E., and probably by a line of thrust from the Leny Grits on the N.W. It consists of black and grey shales, cherts, grits, and calcareous beds, with which are associated some altered igneous rocks. Adjoining the crushed and veined rock which runs along the boundary of the Lower Old Red Sandstone patches of sheared serpentine are seen at several places, sometimes associated with a coarse basic igneous rock somewhat brecciated, as at Maol Ruadh. These probably represent igneous intrusions. Near Loch Lomond grits only are exposed. At the N.E. end, near Callander, the belt consists largely of grits, but at Kilmahog quarry there is a good exposure of black shales with an interbedded limestone identical in character with the limestone in the Margie Series described by Mr. G. Barrow ('Q.J.G.S.,' 1901).

The belt in the Aberfoyle area emerges from under the Upper Old Red Sandstone north of Gualann and extends north-eastwards to a mile N.E. of Aberfoyle. Widest near Gualann—about half a mile. General strike of beds N.E. and S.W., general dip N.W., at high angles. Beds often isoclinally folded along crush planes striking N.E. and S.W. Apparent order of succession from below upwards near Kelty Water: (1) Hornblendic and chloritic schists, probably representing intrusive sheets; (2) Thin band of chert and black shale, only traceable for about a mile; (3) Band of grit which as traced to N.E. comes to abut against Lower Old Red crush rock; (4) Thicker band of black shales and cherts; (5) Grit.—The Leny Grit follows on the N.W., but at other places it appears to come directly on the black shales and cherts.

Difficulty in distinguishing the grits of the Boundary Fault Series from the Leny Grits. The latter are generally greenish, the former greyish and weathering yellowish-brown and are peculiar in containing fragments of black shale, chert, and vesicular volcanic matter. Lumps and courses of a very dark grit also occur in the black shales. The shales are usually black, carbonaceous, staining the fingers, generally very crushed. The cherts are pale grey to dark in colour, often finely banded with frequent interleaves of black shale. Joints and veins at right angles to the bedding often numerous. Thin cherty bands and nodules often

seen in the shales Some of the rocks are a crushed mass of black shale and cherty material. The beds are often distinctly brecciated

Remains of Radiolaria discovered by Dr. Peach some years ago in cherts near Gualann Recently a number of fossils have been found in pale-grey chert bands, 1 to 3 inches thick, in an exposure on S E. side of the Bofrishlie Burn, about 400 yards N W. of Arndrum The fossils occur in muddy films in the chert Belt here only 300 to 350 feet wide. Some of the shales and cherts are thrust over the disrupted edges of the bands which have yielded fossils A little N.W. the cherts are brecciated, and courses of grit occur in the black shales, also showing signs of brecciation. Some calcareous bands occur in the shales in the bed of the stream The fossils are almost all hingeless brachiopods and the following forms have been determined by Dr. Peach —

Acrotreta, sp , *Lingulella*, sp , ? *Obolus*, sp , *Obolella*, sp , also the flattened chætæ of Polychæte worms

The fossils indicate that the Series is probably of Upper Cambrian Age

---

5. *On the Nature of* Parka decipiens *By* ARCHIBALD W R DON, *B A*

This paper was the outcome of an attempted re-investigation of *Parka*, chiefly microscopical, with the aid of Schultz's solution (strong nitric acid and potassium chlorate) Being the only common and quite the most characteristic fossil of the Lower Old Red Sandstone of the Kincardine-Forfar-Perth area, it has naturally attracted considerable attention The nature of *Parka* has been a subject of speculation ever since its discovery at Parkhill in 1831 by Dr Fleming He described it as probably allied to *Juncus* or *Sparganium*, and Hugh Miller, on the whole, agreed as to its vegetable nature Mantell stoutly maintained it to be 'batrachian eggs' Lyell thought it the egg-packet of *Pterygotus*, and this determination was accepted by Salter, Woodward, Powrie, and others In 1890, however, Messrs Reid, Graham, and Macnair, having convinced themselves of its vegetable nature, sent specimens to Sir W Dawson, who, with Professor Penhallow, submitted it to a microscopical examination They clearly showed it to be vegetable, and, after boiling it in nitric acid, demonstrated the presence of spores within the carbonised tissue

The conclusions, other than this main one, arrived at by former investigators have not as yet been confirmed by the present re-examination, the chief results of which, therefore, tend unfortunately to be more destructive than constructive Hitherto no evidence for heterospory has appeared. The 'prothalli' have not been found. The mode of attachment and other vegetative features have not been elucidated, and an agnostic attitude is assumed, pending further discoveries, with regard to those formerly attributed to *Parka*. No evidence has appeared with regard to the supposed varieties '*media*' and '*minor*' An attempt, admittedly tentative, has been made to form some conception of the original structure and shape of *Parka*, based on examination of certain excellently preserved impressions of its two surfaces The main conclusion is that the original spore-containing tissue was almost flat, not spherical (and made up of numerous adjacent lens-shaped spore-sacs)—a structure, in fact, in no way comparable to anything Hydropteridian, and unlike any known sporangia of to-day. There was, certainly, intimately connected with it a so-called 'indusium' Such a reconstruction must, however, be understood to be hypothetical, and not an ascertained fact Certain cell-layers and tissues revealed by the more gentle action of the Schultz's solution may, however, help towards an ultimate solution of the perennial problem of *Parka decipiens*.

---

6 *Uncharted Volcanic Necks at St Andrews* *By* JOHN H. WILSON.

---

7 *Report on the Erratic Blocks of the British Isles*

See Reports, p. 132.

---

8 *Report on the Preparation of a List of Characteristic Fossils* See Reports, p 135.

MONDAY, SEPTEMBER 9.

The following Papers were read —

1 *The Sequence of Volcanic Rocks in Scotland in relation to the Atlantic-Pacific Classification of Suess* *By* JOHN S FLETT, *M A , D Sc*

The recognition of two great families of igneous rocks, the Atlantic and the Pacific, and their relation to certain types of earth-movement, which we owe to Harker, constitutes one of the greatest advances in rational petrology

In Scotland we may take the Carboniferous volcanic rocks as typically Atlantic, while the volcanic rocks of Lower Old Red Sandstone age are characteristic of the Pacific group We may add to the Atlantic two other series, the Permian or late-Carboniferous volcanic rocks of Ayrshire and East Fife, and the nepheline-basalts (presumably Tertiary) of Caithness, with their associated camptonites and monchiquites

The Tertiary volcanic rocks of the Hebrides are Atlantic and are associated with movements of Atlantic types There is much reason in ascribing also to this period the north-west dykes, so abundant in Scotland, which contain not a few nepheline-bearing rocks

The remaining volcanic rocks of Scotland are of distinct type They comprise the Tayvallich lavas (perhaps pre-Cambrian), the Upper Cambrian volcanic rocks of the Highland border, and the silurian (and ordovician) lavas of the Southern Uplands Pillow-lavas with Keratophyres, &c , characterise this group They are not connected with movements either of Atlantic or of Pacific kind, and may be placed in a special family

2 *The Older Granite in Lower Dee-side* *By* G BARROW

A brief description was given of the mode of occurrence and composition of one of the older Granite intrusions in Lower Dee-side In place of forming large coherent masses it tends rather to minute subdivision, permeating the crystalline gneisses over large areas Excellent examples of lit-par-lit intrusion may be seen on the north side of the Dee, about, and west of, Banchory The granitic material in these cases forms minute sills, varying from an inch to several feet thick, and almost rigidly parallel to the foliation of the associated gneiss into which it has been intruded The ground here is comparatively flat, and the method of feeding the sills cannot be clearly made out But on the opposite or south side of the river the ground is much steeper, and in the hill-faces dyke-like intrusions can be seen, from which the sills proceed They commence a little below the crest of the dyke, where they are smallest and shortest, they are seen to become steadily thicker and longer as we descend further below the crest of the dyke In the interior of the latter the granite is usually grey, and contains more biotite than muscovite, oligoclase is also usually abundant, the oligoclase and biotite steadily diminish in amount as the rock is traced towards the taper end of the sills At this point there is little oligoclase, and often no biotite, muscovite is fairly common, often in large crystals, and the bulk of the felspar is of alkaline composition It appears that the fissures in which the dykes occur were filled with igneous material, and that under great pressure the walls were burst open and the still liquid material forced out, and thus separated from that which had already segregated out. The phenomenon may be described as magmatic differentiation intensified by dynamic action Further, the material (pegmatite) which occurs on the extreme ends of the sills is often far coarser than that met with in the centre

of the dyke; the distribution of coarse and fine material being thus the reverse of that usually met with in small intrusions.

This separation of the more acid and less acid material occurs in connection with every dyke and sill over the entire Dee-side area between Banchory and Aberdeen, the pegmatitic material forming a fringing margin, the breadth of which varies considerably. The largest of the sill-like masses occurs at Aberdeen, and part of the city is built on it, its great fringe of pegmatite veins is well displayed on the banks of the Dee near the railway bridge

The separation of the material rich in oligoclase and biotite from that richer in alkali-felspar and muscovite is not confined to each separate intrusion, it holds good for the intrusion as a whole Well to the south of the Dee, especially nearer the coast, nearly the whole of the intrusions are more alkaline than those nearer the Dee, the pegmatite remains of much the same composition, but there is a considerable amount of schorl present in the southern area that is distinctly rare in the northern

There is considerable variation in the amount of foliation shown by these intrusions In the moderate sized or larger ones the centre is usually unfoliated, or but slightly so, toward the margins the foliation is more marked. The pegmatite fringe is rarely foliated if it occurs as veins or dykes; but it usually is more or less foliated if in thin sills The foliation over most of the area is protoplastic, post-consolidation crushing is rare Indeed, it is only well seen in one case, where the granite has reached the present surface far south of the main series of intrusions, and within a lower temperature zone This intrusion is cut open by a branch of the Cowie Water, close to the Stonehaven Road from Banchory

---

3 *The Alkaline Igneous Rocks of Ayrshire* By G W Tyrrell

Recent work by Scottish petrologists has disclosed the fact that one of the greatest developments of rocks characterised by primary analcite as yet discovered is contained in the Midland Valley of Scotland Geographically these rocks are localised in two main regions one in Ayrshire, the other in the districts surrounding the Firth of Forth There are also one or two subsidiary districts, as, for example, the neighbourhood of Glasgow Geologically the analcite rocks, both intrusive and extrusive, are Carboniferous in age, and have a time-range extending from the Carboniferous Limestone to the very latest Carboniferous date in Scotland, possibly including also the early Permian

The Ayrshire region is practically bounded by the confines of that county The intrusions of the analcite-suite penetrate the stratigraphical series from the Calciferous Sandstone to the lavas overlying the Upper Red Barren Measures of the Mauchline district They occur in the form of stratiform sills, lenticular intrusive masses, volcanic plugs, and as a series of lava flows No masses of true plutonic habit are known In this igneous episode, therefore, there are representatives of the volcanic phase and the phase of minor intrusions, but not the plutonic phase It may be assumed that the latter, if developed at all, is still deeply buried, and has not yet been exposed by erosion

The petrological characters of the suite are very distinctive In general the magmas were poor in silica and rich in alkalies, and in the latter soda is always in excess of potash The rocks were so saturated with magmatic water that the characteristic mineral of the suite is analcite, which occurs in almost every member, sometimes abundantly, and with such relations to the other constituents as to establish its undoubted primary character. The characteristic femic mineral is a purple titanaugite. Olivine is also abundant, and some of the rocks contain soda-amphiboles (barkevicite and arfvedsonite). Nepheline and soda-orthoclase occur in subordinate amounts, and aegirine is found in the more acid rocks

The rocks have been classified as follows —

A *Rocks with conspicuous Analcite*

1 *Analcite Syenite* —In which alkali-felspar is dominant with abundant fresh interstitial analcite.

2. *Teschenite* —In which lime soda felspar is dominant Three types are

distinguished, on mineralogical and textural grounds, as the Glasgow, Galston, and Cathcart types

3 *Picrite-Teschenite* —An ultra-basic differentiation facies of teschenite Two types are distinguished, the Inchcolm and the Lugar, the latter being characterised by granular augite and abundant hornblende.

4 *Lugarite* —A leucocratic rock analogous to ijolite, containing about 50 per cent of analcite and nepheline with titanaugite, barkevicite, and labradorite

5 *Monchiquite* —A lamprophyric type usually occurring as a contact-facies, but occasionally as an independent mass One occurrence contains huge phenocrysts of hornblende and biotite

B *Rocks with conspicuous Nepheline*

1 *Theralite* —Two types are distinguished one, the Bellow type, occurring in the picrite-teschenite sill of Lugar, is characterised by melanocratic habit, abundance of olivine, and poikilitic fabric, the other, the Barshaw type, is also melanocratic, but the chief coloured minerals are titanaugite and barkevicite

2 *Essexite* —Two types are recognised the Carskeoch and the Crawfordjohn, the latter characterised by porphyritic augite and rather abundant nepheline

3 *Kylite* —An olivine-rich, melanocratic end-facies of the essexite or theralite families, occurring as a homogeneous set of sills and bosses in the Kyle district of Ayrshire

C *Rocks without conspicuous Analcite or Nepheline*

These rocks show their relations to the alkaline series by the abundance of purple augite and occasional nepheline, analcite, or soda-orthoclase They are designated alkali-dolerites and essexite-dolerites, and some of them closely resemble the crinanites of Argyllshire

D *The Extrusive Rocks of the Mauchline Basin*

The lavas comprise femic olivine-basalts (Hillhouse and Dalmeny types), analcite basanites, analcite-nepheline-basanites, nepheline basalts, monchiquite-lavas, and limburgite

Of the above types, teschenite is by far the most abundant amongst the intrusive, and olivine-basalt in the extrusive rocks The available evidence goes to show that the earliest rocks to be intruded were the teschenites, and that they were followed, in the order named, by picrite-teschenite, kylite and essexite, analcite-syenite, and essexite-dolerite The Mauchline lavas were probably the effusive equivalents of the kylites and essexites

---

4 *The Volcanic Rocks around the Ord Hill of Rhynie, Aberdeenshire* *By* WILLIAM MACKIE, *M A , M D.*

These rocks occupy an area of two-thirds of a mile in length by a quarter of a mile in breadth, of which Ord Hill marks the centre, about half a mile west of the village of Muir of Rhynie, West Aberdeenshire The group embraces at least three independent lava flows, with associated tuffs and interbedded and overlying sedimentary rocks, and lies on an eroded, eastward-sloping surface of the diorites and gabbros of West Aberdeenshire—rocks which have been considered to represent an early and basic modification of the younger Grampian granite—and are cut off on the east by the boundary fault of the Old Red Sandstone outlier of Rhynie and Kildrummy A small outlier limited to two or three square yards of surface, and representing a single lava flow, lies on the edge of the serpentine mass of Cnoc Cailliche about a mile south from the extreme southern end of the main area The volcanic members of the group consist of grey to greenish coloured rhyolites, showing in places fine vesiculation and beautiful fluidal banding. The usual minerals of such rocks—quartz, orthoclase, muscovite, biotite with at times an occasional augite, are present in an amorphous base Flow-brecciation is a frequent feature and evidence of the effect of pressure is not entirely absent The tuffs consist of fragments of rhyolite rocks—occasionally up to 2 inches in diameter—often rounded and encircled with glassy coronas exhibiting fluidal banding. Broken crystals of quartz

and orthoclase as well as considerable fragments of older tuffs are also present. The sedimentary rocks of the group consist of very hard siliceous grits which, on microscopic examination, often show the presence of fragments of volcanic rocks of the same general characters as the associated lavas These fragments are generally larger in size than the accompanying fragments and grains of sedimentary origin The whole of the group is characterised by the presence of numerous, often very fine, secondary quartz-infiltrated veins, and at one part in the sedimentary division these veins make up quite half the bulk of the rock.

Two small masses of biotite granite containing much microcline break through the diorite immediately to the west of the area With these the volcanic members of the group may or may not have a genetic relationship.

As regards the age of these rocks, it is impossible to arrive at a very definite conclusion They are manifestly younger than the diorite, but are probably considerably older than the oldest beds of the Old Red Sandstone of the adjoining area The lavas being throughout of acid type, it is evident that they cannot be correlated with the interbedded andesites of the local rocks of Old Red Sandstone age

5 *On an Actinolite-bearing Rock allied to Serpentine* *By* A W Gibb, *M A* , *D Sc*

This rock is associated with the intrusion of basic rocks in Belhelvie, Aberdeenshire Towards the northern end of this mass, which consists of troctolites, serpentines and allied types, a rock is occasionally met with which differs in some respects from the varieties common in the district In its most typical development it shows a large number of dark-green rounded spots set in a fine felt of paler green colour, full of glancing needles Most of the specimens show a more or less clearly defined banding or schistosity The affinities of the rock are somewhat obscure in hand-specimens But under the microscope the dark spots are seen to represent olivine, which is still partly unaltered but partly serpentinised, as well as granulitised and drawn out The rest of the rock is largely made of actinolite in small crystal flakes, there are also present a green spinel, abundant magnetite, and sometimes other ingredients In most varieties there is no trace of felspar This rock passes into varieties in which the spots are much less obvious, and finally grades into a rock that might be described as an actinolite-schist

The exposures of this rock, so far as they have been mapped, lie mostly on the outer fringe of the basic intrusion, and therefore close to the line of junction with the metamorphic rocks into which the igneous rocks have forced their way From its field relations and its general characters it is clear that it represents a type of the basic rock which has undergone actinolitisation on an extensive scale The original rock from which it is derived must in most cases have been an olivine-enstatite rock, more or less completely serpentinised, or else a very basic troctolite Although actinolitisation is widespread in this, as in other metamorphic areas, a rock of this particular type has not been noted in this locality before It has nowhere been found in large mass, and seems essentially a marginal phase The most prominent exposure yet met with is, or was, a clump in a field adjoining the Udny Road, immediately south of 'Skelly-hill Wood ' This exposure has recently been entirely blasted away, and it seemed desirable to make a definite record of its occurrence

6 *On the Origin of some of the Mica-Schists of Anglesey* *By* Edward Greenly

In the south-east and centre of Anglesey extensive tracts of country are occupied by mica-schists in which it is a very rare thing to find any survival of original structures They are holocrystalline rocks, usually with strong parallel structure, and composed essentially of quartz, alkali-felspars, and white mica. In certain compact varieties, however, especially about Y Graig, Holland Arms, traces of felsitic texture can be found. Dr. Teall, who has examined the rocks in the field as well as under the microscope, regards them as in all probability

broken down and partially reconstructed porphyritic felsites, and considers that some lenticular aggregates which they contain may be looked upon as broken-down porphyritic felspars Twenty-five years ago Dr Callaway recognised the felsitic origin of these rocks, and the present investigations fully confirm his conclusion [1] Similar structures have now been found in the rocks of the central area, on its western coast near Trecastell These schists, therefore, may be looked upon in general as derived from acid igneous rocks In other parts of both areas, however, mica schists in continuity with them are found in intimate relations to schists of sedimentary origin, so that it is probable that pyroclastic material was present in the original igneous series

7. *The Millstone Grit of Yorkshire Some New Evidence as to its Source of Origin.* By ALBERT GILLIGAN, *B Sc*

More than fifty years ago Dr. H C Sorby attempted to trace the source whence the material which makes up the Millstone Grit had been derived, by making a collection of pebbles which occur so abundantly in some of the beds Among these he found some small fragments of mica-schist, quartz-schist, and a few pebbles of undoubted granite The largest pebble he obtained was about four inches in circumference and of a type resembling a fine grained syenite or greenstone, but too much decomposed to be accurately identified The pieces of granite were composed of quartz and felspar, suggesting by their appearance derivation from coarse-grained granites Pebbles of quartz he found to be commonest, and he also described some pieces of white or brownish orthoclase felspar

The granites he found were quite unlike any with which he was acquainted in the British Isles, being too coarse and much more like those of Scandinavia Further, the current bedding, which Dr Sorby examined over an area of twenty-five square miles, pointed to a drifting from the north-east, and he therefore suggested some south-westward prolongation of an ancient Scandinavia as the source of origin of the material making up the great mass of the Millstone Grit of Yorkshire Since this early work by Dr Sorby nothing has been added to our knowledge of the lithology of this, to most people, uninteresting series of rocks The late Mr A Longbottom, B A , of the Nigerian Survey, collected some very large pebbles from the Middle Grits of Silsden These have been examined by the author, who has also extended his researches into the other beds of the series in various parts of Yorkshire Some of the pebbles are of a very large size, one obtained from Netherwood Plantation Quarry, Silsden, measures 10 inches by 8 inches by 3 inches, and is a reddish granitoid rock with large porphyritic felspars The pebbles show a remarkable assemblage of rocks, igneous, sedimentary, and metamorphic all being represented, but by far the commonest are acid igneous rocks—granites, quartz and felspar porphyries Only one specimen of basic igneous rock has been found The metamorphic rocks are quartz-schist and mica-schist with a few fragments of gneiss One of the mica-schist pebbles has been identified by Mr. Barrow as similar to a rock described by him occurring in the Moine Schists of the East Central Highlands Numerous pebbles of felspar have been examined by the author and in each case found to be perfectly fresh microcline, the cross-hatching being beautifully clear Pieces of pegmatite, the constituents being quartz and microcline, are very common in all the beds, but most abundant in the Kinderscout Grit and Rough Rock Some fragments obtained from the Plompton Grit at Knaresborough proved to be a peculiar silicified oolitic rock, the outlines of the oolitic grains being traced out by small rounded bodies stained red or brown A few pebbles show undoubted traces of organisms such as sponge spicules, &c

The heavy minerals of the grit are not numerous, the most plentiful being zircon and garnet The felspars in the grit, both large and small, are quite fresh when first exposed, and this suggests either disintegration of the parent rock by differences of temperature and rapid transportation, or comparative absence of carbon dioxide in the atmosphere. The author has been much

[1] See *Brit Assoc Report,* Manchester, 1887, also *Q J G S* , 1897 and 1902

impressed by the many points of similarity existing between the Millstone Grit and the Torridon Sandstone, and is disposed to think that areas of similar rock types were laid under contribution for each.

8. *Notes on the Volcanic Rocks and their Associated Sediments of the Forfarshire Coast between the Red Head and Montrose* By ALBERT JOWETT.

TUESDAY, SEPTEMBER 10

The following Papers and Reports were read —

1 *The Fossil Flora of the Pettycur Limestone in relation to Botanical Evolution* By W T GORDON, *M A , B A , D Sc*

The oldest flora of which we have any considerable knowledge is that represented in Upper Devonian rocks, but the plants obtained from Lower Carboniferous strata do not differ markedly from the Devonian types and so may be included in the Devonian flora Examples of petrified plants of Lower Carboniferous age have been recorded from several localities in Scotland, but they are nowhere so abundant as at Pettycur, near Kinghorn, Fife The flora of the Pettycur Limestone, then, has a double interest, the remains constitute fragments of the oldest known flora, and, as they are petrified, the internal structure of these plants may be studied

Although the Devonian flora is very distinct from that of the succeeding Permo-Carboniferous epoch, yet the organisation does not indicate that the plants were primitive Indeed, all one can say is that the assemblage, as a whole, appears to be less highly specialised than that represented in Upper Carboniferous strata

As the horizon of the Pettycur rocks is rather high in the Calciferous Sandstone Series, we would expect to find some species whose structure indicated a transition between Devonian and Upper Carboniferous forms In some cases I believe that such specimens have been discovered For example, we find several genera belonging to one order, or several species to the one genus, and in such cases one form is more generalised in structure than the others, while the less generalised forms appear to be more closely allied to Upper Carboniferous types

Among the *Lepidodendra*, for instance, *Lepidodendron Pettycurense*, Kidston, has a perfectly solid central axis, the xylem cylinder in *Lepidophloios Scottii*, Gordon, is occasionally solid in places, but at other parts of the same specimen a mixed pith, consisting of parenchyma and short tracheides, may be noted *Lepidodendron Veltheimianum*, Sternb , on the other hand, has a well-marked parenchymatous pith containing no tracheides A line of development is thus suggested by this series, and when we turn to the Coal Measure flora a parallel series may be shown The lowest member among the Upper Carboniferous *Lepidodendra* has a mixed pith, and hence we conclude that the Pettycur plants show less specialisation than those of a later date, though the organisation is similar in each case Such parallel series may also be demonstrated in other groups, particularly among the ferns and pteridosperms

The various reproductive members met with at Pettycur also exhibit certain peculiarities The most complex cryptogamic cone yet discovered—*Cheirostrobus pettycurensis*, Scott—was recorded from this locality Certain characteristics common to several groups are combined in the cone, which is thus both complex and generalised.

In the megaspore of *Lepidodendron Veltheimianum*, Sternb , the archegonium has been recorded, and it does not differ from that of the living *Selaginella* or *Isoëtes*

To sum up, then, the flora represented in the Pettycur Limestone appears, on the whole, to contain more generalised and simpler types than occur in the Coal Measure and later strata, and these types may be arranged in order so as to suggest certain possible lines of evolution.

2 *Palæobotany* versus *Stratigraphy in New Brunswick* *By* MARIE C STOPES, *D Sc*, *Ph D*, *F L S*

Outline of the controversy, which dates from 1866 The so-called 'Fern Ledges' near St John, New Brunswick, have a rich fossil flora but almost no animal remains Sir W Dawson described the plants as Devonian Confusion still exists owing to the mixture of true Devonian plants from Gaspé, &c, in the same monograph of Dawson's Recent attempts include the beds in the Silurian, for 'stratigraphic' reasons The necessity of field work as well as palæontological determinations The author's work in the field; notes on relative dips of the beds, the so-called 'slates,' intrusive rocks, and contortions Observations indicate existence of considerable overthrust Palæobotanical data Re determination of supposed 'unique' species Type specimens lent by the Canadian museums and brought to London and Paris for comparison with standard collections, resulting in identification of a large proportion of well-known European types in the 'Fern Ledges' flora, all Carboniferous and mostly typical of Westphalian division in Coal Measures. Note the value of fossil plants, as the Carboniferous age of the beds was recognised by Geinitz in 1866 from a single specimen of a fern-leaf The author did the work for the Canadian Geological Survey, to the kindness of whose Director is due the permission to give this résumé of the results

3 *The Pre-Cambrian Rocks of Western Carnarvonshire* *By* Dr C A MATLEY

4 *The Archæan Rocks of Lewis* *By* B N PEACH, *LL D*, *F.R S*, *and* J HORNE, *LL D*, *F R S*

During 1911 the authors visited Lewis with the view of comparing its Archæan Rocks, previously described by Macculloch, Murchison, Heddle, and James Geikie, with the types of Lewisian gneiss mapped by the Geological Survey along the western seaboard of Sutherland and Ross The areas examined comprised sections taken at intervals along the east coast from Tolsta Head, north of Stornoway, to near Loch Bhrollum, opposite the Shiant Isles—a distance of about thirty miles, and along the west side from the Butt of Lewis to Carloway—a distance of twenty-five miles Traverses were made across the island (1) from Barvas on the west to Stornoway on the east, thence over the Eye peninsula to Tiumpan Head; and (2) from Carloway by Callernish to Keose on Loch Erisort, and Stornoway

A large series of specimens was collected and submitted to Dr Flett for examination, who has furnished a valuable detailed report showing wherein they resemble and wherein they differ from types described by Dr Teall in the *Geological Survey Memoir*, on 'The Geological Structure of the North-west Highlands of Scotland' (1907) Dr Flett has arranged the specimens in the following groups: (1) muscovite-biotite gneiss, (2) biotite-gneiss, (3) biotite hornblende-gneiss, (4) hornblende-gneiss, (5) pyroxene-gneiss, (6) hornblende schist, (7) pyroxenite, (8) pegmatite-gneiss, (9) granite-gneiss, (10) mylonite

In the various sections examined throughout the island, rocks belonging to groups (2), (3), and (4) are the main components of the Archæan Complex They are intimately associated with each other, and have a common foliation The muscovite-biotite-gneisses (1) occur together with the biotite-gneisses, but they are not abundant The pyroxene-gneiss (5) is recorded only from one locality, viz, Dalbeag, near Carloway, where it forms part of a basic mass which is cut by the foliated granite of Carloway (9). The hornblende-schists (6) constitute basic masses in the complex, with a foliation more or less parallel with that of the contiguous gneisses The relative age of the members of this group has not been definitely ascertained The pegmatites and pegmatite-gneiss (8) intersect the other components of the complex, but they are sparingly represented compared with the great development of these types on the mainland between Laxford and Cape Wrath One example of pyroxenite (7) was obtained in the policies of Stornoway Castle Mylonites (10) are typically developed in

certain sections along the eastern seaboard between Tolsta Head and Loch Bhrollum

In the areas examined, the north-west and south-east strike, referred to by Murchison, is not characteristic of the gneisses of Lewis It is prevalent immediately to the west of Stornoway, but exceptional in other tracts In this connection the observations of Professor James Geikie in the Eye peninsula were confirmed The dominant strike over extensive areas runs a few degrees east of north and west of south, in certain localities it is north-east and south-west, and in others nearly east and west

The prevalent types of gneiss closely resemble those to be found on the mainland between Loch Laxford and Cape Wrath, without the great series of acid intrusions The structure is coarsely granular, or granulitic, the mineral grains being rounded and not elongated The range of rock types seems to be comparatively limited, for there is a marked absence, in the areas examined, of the pyroxene-gneisses with blue quartz, of pyroxene-granulites, and other basic and ultrabasic materials, which are so characteristic of the Fundamental Complex between Lochinver and Scourie on the mainland The remarkable series of basic and ultrabasic dyke intrusions in the west of Sutherland has not been detected in Lewis

The flaggy granulitic gneisses of the Butt of Lewis which appear to run southwards along the belt of high ground between Stornoway and Barvas are of special interest In structure they closely resemble the Moine gneisses east of the Moine thrust-plane, but they differ petrologically from the rocks of sedimentary origin that form the Moine series of the Geological Survey The system of over-folding and the direction of the axial planes of the folds approximate to those found in the Moine rocks on the mainland

The platy rocks or mylonites, noted by Macculloch, occur along definite lines of movement, trending a few degrees east of north and west of south Actual thrust-planes have been detected, which are inclined to the south of east at low angles, as if the displacements had been in a westerly direction Various stages in the development of mylonites from the acid and basic gneisses are represented

5. *The Settlement and Transport of Sand in Water* *By* J S Owens, *M D , A M Inst C E , F G S*

This paper described experiments on (*a*) the effect of the water temperature on the rate of settlement of sand, and (*b*) the rate of transport of sand along the bottom under the influence of a current, and its relation to the velocity of the current

It was shown that there is a definite relation between the rate of settlement and the temperature of the water, and tables and curves were given showing what this relation is The experiments described were made with siliceous sand from the sea-shore in most cases, and dealt with grades from a diameter of three up to fifty-five thousandths of an inch, that is, from an almost impalpable powder to coarse sand The curves show that velocity of fall varies almost directly with the water temperature, the rate being always increased by rise of temperature, but that as the diameter of grain increases the temperature effect becomes less, until for grains over one-tenth inch diameter the effect is practically negligible The bearing of the investigation on silting and suspension of matter in water was dealt with Warm water would have less suspending power than cold, and therefore less erosive power Silt-laden rivers must deposit their load more rapidly in warmer than in colder seas, this must affect the growth of deltas The sea has probably less erosive power on the coast in summer than in winter, other conditions being the same

The experiments on sand transport along the bottom, which were described, refer only to that stage in which sand moves in ripples, that is, under the influence of currents of from about 1 to 2½ feet per second At the former ordinary sea-sand begins to move in ripples, and at the latter the ripple movement ceases and a new method of transport in a sheet, or long flat waves, begins Tables and curves showing the relation between the velocity of ripple movement and that of the current were given, and this relation was shown to be

approximately given by the equation $V=\frac{v^6}{5}$, in which V = velocity of ripple in feet per hour, and v mean velocity of current in feet per second The volume of sand moved per hour along a strip 10 feet wide is shown to be approximately $=0\ 0476\ v^6$ cubic feet, that is, within the limits of the experiments, the volume of sand moved varies practically as the sixth power of the mean velocity of the current

This result differs slightly from D F Deacon's[1]; he states that the weight of sand moved was proportionate to the fifth power of the surface velocity, possibly a little more The practical importance of the experiments lies in being able to deduce from the velocity of the current the quantity of sand being moved along the bottom

---

6 *On the Recent Earthquakes* *By* Dr J MILNE, *F R S*

7 *On Buckled Folding* *By* G BARROW

A number of descriptions has been published of portions of areas of regional crystalline metamorphism in which the dip of the bedding, or in some cases the dip of the foliation, is described as being at a low angle over a considerable area These descriptions are at times so worded as to convey the impression that this represents the original and but slightly disturbed bedding of the altered sediments Experience is gradually proving that the altered sediments in such areas are always intensely folded, and the detailed examination of the Highlands suggests that in place of these long-continued low dips being due to small disturbance, they really represent the most complicated form of structure, for which the name of 'buckled folding' is suggested

The best known illustration of the phenomenon in this country is afforded by the gneissose-flagstones or Moine gneisses The deceptive nature of the dips in the rocks was soon recognised by the officers of the Geological Survey of Scotland, who found that in cliff sections the beds really ascended the cliffs by a zigzag course, to which the term 'lightning-structure' was applied

The mode of production of this 'zigzag' structure can be traced on the cliffs between Stonehaven and Muchalls, in Kincardineshire The rocks in these cliffs consist of alternations of grits, gritty shales and shales, becoming more and more crystalline as we proceed northward Nearer Stonehaven the bands of grit may be seen to ascend the cliffs in an unbroken or unbent course from bottom to top, having a high dip in a northerly direction The limbs of the folds are thus isoclinal and unbent But as we proceed northwards the course of the grit bands up the cliff face is no longer straight, a small overfold or 'buckle' is developed on it At first only one is seen in the whole height of the cliff, further north two occur, then three, and so on, till at last they are so close together that the still straight portion of the fold is little, if at all, longer than the 'buckled' or overfolded portion If the upward course in the cliff of each grit band be carefully followed it will be found that the oncoming of this 'buckling' structure does not alter the dip of the band as a whole, it still ascends at much the same angle, only it pursues a more zigzag course The overfolds or buckles all face the same direction right up to Muchalls, and a little consideration will show that this 'buckling structure' must have been produced after the isoclinal folding was completed There is thus no evidence to suggest that the rocks in which the buckling structure has been developed should be separated as a different series from those in which it does not occur In the interior of the south-eastern Highlands this structure is present in all but the southern margin of the area, till we reach the first outcrop of the Highland quartzite, where the buckling rapidly ends and the earlier isoclinal folding is left unaltered For a distance of some seven or eight miles the buckling structure is either very rare or absent, but it sets in again in the quartzite close to Braemar It is there also shown both by the marginal sandy beds, known as the Moine gneisses, and the dark schist next them There also is no justification for separating the beds with the superinduced 'buckling

[1] *Min Proc. Inst C E*, 1894, vol 18

structure' from those without it, as has been generally done. A key to the connection between the 'buckled' and 'non-buckled' areas occurs in the ground about Shiehallion and to the north (Sheet 55, Scotland). At Shiehallion we have the quartzose beds forming the margin of the quartzite, and containing the boulder bed and the limestone close by; further north we have the same group again. In the first case we have isoclinal folding, in the second, buckled folding, or Moine gneiss.

8. *The Heavy Mineral Grains in the Sands of the Scottish Carboniferous.* By T. O. Bosworth, *B.A., B.Sc., F.G.S.*

These observations were made at the commencement of an investigation which the author has now no opportunity to carry on.

The chief heavy grains are:—

Garnet, which, though in some sands practically absent, in others is in such excessive quantity as to almost mask the presence of other grains.
Zircon, always present, and sometimes the most abundant species.
Magnetite, always present.
Tourmaline, always present.
Rutile, always present, but varies widely in quantity and characters.
Staurolite, often present, but not plentiful.
Anatase, occasionally present in noticeable amount, as well-formed plates of steel blue colour.
Barytes, found in a few cases in large amount. It is probably a cement, though well-formed crystal-plates occur. Sandstones containing this cement are very hard. I find it in several building-stones.

Characteristic of all the grains is their angularity. The garnets have the dodecahedral cleavage developed out in a remarkable manner, so that the grains have elaborate zigzag shapes with innumerable corners and edges. The contrast between these heavy grains and those in desert sands is much more marked than in the case of quartz.

The heavy mineral contents prove the sands to belong to at least two entirely different kinds:—

(*a*) Sands in which the heavy mineral grains consist mainly or largely of garnet.

(*b*) Sands in which garnet is absent or scarce.

Vertical and Lateral Distribution.—The amount of evidence yet collected is only sufficient to be suggestive of the kind of results which may be obtained.

In the following list o denotes garnetiferous, × denotes non-garnetiferous. (Measurements in bore sections are actual, and are not corrected for inclined strata.)

Red Measures.

o Rutherglen.

Coal Measures.

o	Cambuslang	above Humph Coal
o	Chapelhall, Shottsburn	24 feet above Lower Drumgray Coal.
o	Chapelhall, Shottsburn .	just above Lower Drumgray Coal
o	Chapelhall, Shottsburn	" " "
o	Fauldhouse Quarry	above Crofthead 4 feet Coal.
×	Chapelhall, Shottsburn	below the Coals, faulted, and near Millstone Grit.

Millstone Grit.

×	Bilston Burn, near Edinburgh	Roslin Grit.
×	Glasgow, Blochairn Quarry .	above fireclays
×	Muirhouse Bore, Lanarkshire	depth 30 feet.
×	Muirhouse Bore, Lanarkshire	depth 174 feet.
×	Levenseat	above Curdley Ironstone.
×	Balfour Bore, Fife . .	12 feet above Levenseat Limestone horizon.
o	Bilston Burn . . .	6 feet above Castle Carey Limestone horizon.

Carboniferous Limestone Series.

o	Balfour Bore, Fife	36 feet below Calmy Limestone horizon.
o	Bilston Burn	100 feet below Calmy Limestone horizon.
o	Balfour Bore	360 feet above Index Limestone
×	Giffnock	270 feet " " "
o	Balfour Bore	150 feet " " "
o	Bilston Burn	12 feet " " "
o	Bishopbriggs, Hunters' Hill	just " " "
×	Kirkintilloch	40 feet below Index Limestone
o	Linlithgow	200 feet " " "
×	Bilston Burn	540 feet " " "
×	Balfour Bore	798 feet " " "
o	Balfour Bore	1,242 feet " " "
×	Balfour Bore	1,374 feet " " "
o	Bilston Burn	5 feet below Hosie Limestone horizon.
×	Bilston Burn	10 feet above North Greens Limestone.

Calciferous.

×	Milngavie	above the Traps and below Hurlet Limestone.
×	Burntisland, Grange Quarry.	about Burdiehouse horizon
×	Hailes Quarry.	
×	Craigleith.	

Conclusions and Suggestions—The sands containing such an extraordinary quantity of angular garnet have been derived from the Highland schists to the north and north-west of the basin, whilst the sands devoid of garnet are likely to have come from the north-east, east, or south.

It may be possible by a study of the heavy mineral grains and of the current bedding, and the thickening and thinning of the beds, to subdivide the whole of the Carboniferous accumulation into a number of great lens-shaped or wedge-shaped bodies of sediment, which have been introduced from various directions and are interdigitated in a complex manner These great lenticles might be expressible on maps, and might be helpful in explaining the lateral changes and the distribution of the coals

---

9 *Report on the Excavation of Critical Sections in the Palæozoic Rocks of Wales and the West of England*—See Reports, p 136

10 *Interim Report on the Microscopical and Chemical Composition of the Charnwood Rocks.*

---

11 *Report on the Investigation of the Igneous and Associated Rocks of the Glensaul and Lough Nafooey Areas, Co Galway*—See Reports, p 143

WEDNESDAY, SEPTEMBER 11

The following Papers were read —

1 *A Theory of the Menai Strait* By EDWARD GREENLY

Ramsay's view of the strait as a glacial furrow was in the main accepted, but it was shown, from the general glacial phenomena, and from soundings, that the middle reach of the strait cannot be explained in that way Evidence was adduced to show that this reach was excavated by glacial waters during the recession of the ice at a time when the mutual relations of the ice of the

mountain-land and of the sea-basin admitted of the accumulation of a temporary lake Post-glacial erosion and subsequent changes of level have completed the bed of the strait as it now exists

2 *The Origin of Kopjes and Inselberge* By J D Falconer, *M A*, *D.Sc.*

Detached hills, projecting crags, and isolated rocks are features of almost every landscape, and in the moister regions of the globe their origin has usually been correctly assigned to the ordinary processes of denudation They may arise either through the dissection of earlier plateau-surfaces, as frequently in the case of detached flat-topped and pyramidal sandstone hills, or by the weathering out of the more resistant units where the surface is composed of rocks of different degrees of hardness, as in the case of escarpments and of detached crags and hills of igneous rock The kopjes and island mountains of the warmer temperate and tropical regions are essentially of similar origin, but, on account of the present climatic conditions being in many cases different from those under which they were formed, their actual mode of origin has given rise to considerable discussion A striking feature of these kopjes and inselberge is that they rise at intervals from an apparently level or gently undulating plain, which in most, if not all, cases should be regarded as a former base-level of erosion The typical kopjes of South Africa are of sandstone, shot with veins and dykes of igneous rock, which has given them the necessary power of resistance to the agents of erosion The old crystalline regions of Africa, however, are dotted with domes and turtlebacks of granite and detached groups of granite hills, which represent the more resistant elements of the crystalline complex Some of these isolated hills possess flattened caps of weathered rock, and it seems probable, therefore, that the sculpturing of the original crystalline surface was due, not so much to the direct erosion of the unweathered rocks, as to the effect of periods of elevation and erosion following upon periods of decomposition *in situ* at base-level As the result of erosion a somewhat irregular surface would be produced, but a slight subsequent negative movement would suffice for the obliteration of the minor irregularities and the consequent accentuation of the less weathered portions of the surface The repetition of such a cycle would lead to the increased prominence of the earlier hillocks and the formation of others of lower level It has been suggested that a landscape with inselberge is of desert origin, but the various phenomena can be explained more readily as the result of weathering and erosion during successive small oscillatory movements of a regional character in the neighbourhood of base-level

3 *Note on the Country North of Lake Albert* By G. W. Grabham

4 *Secondary Quartz on Pebbles* By G W Grabham

5 *Post-Glacial Changes of Level* versus *Recent Stability of the Lake Region of America* By Dr J. W Spencer

About the lake region extensive beaches, now raised, have their former water-levels deformed by rising towards the north and east The tilting was recognised as early at 1851 (by Professor Stoddard) to have been due to earth movements

At the period referred to the lakes were larger than at present, and differently grouped, forming Lakes Warren, Algonquin, and Iroquois, discovered and named by the author From their abandoned shore-lines it is found that between the head of Lake Ontario and a point near its outlet (at Watertown, N Y) there is a rise of land from 363 to 730 feet above sea-level, or 367 feet If the uplift be taken from the head of Lake Erie to the same point (400 miles), it amounts to 507 feet

Calculating the mean direction in various triangles, the change is found to be reduced to almost zero at the head of Lake Erie; two feet per mile, N. 22° E,

about the head of Lake Ontario; and due north just beyond the eastern end of this lake, where it rises from three to six feet per mile on proceeding northward.

The ellipse or focus of maximum uplift is situated near latitude 49° N and longitude 76° W, or near the height of land between the lakes and Hudson Bay. The deformation, as about Lake Huron, continued to so recent a date as subsequent to 3,500 years ago (found from its effects on Niagara Falls)

The daily records of the lake fluctuations have been kept since 1854 Taking the mean at certain points for five-year periods, the errors are largely eliminated Between the periods 1855-59 and 1906-10 there have been absolutely no movements of the earth's crust over a drainage area of 300,000 square miles during over fifty years This result is in contrast with that obtained by Dr G K Gilbert's taking a few odd fluctuations at the same points, giving a rate of movement that it is now found does not obtain

Recently the cessations of changes of level off the eastern coast of America have been shown by Dr D W Johnson, who finds that if there be such in progress they do not equal a foot a century This is also in contrast with the submergence of the valleys along our coast line

6 *On a Fossiliferous Tufa occurring beneath Chalky Boulder Clay at Launde, Leicestershire* By A R Horwood

In the Report on Erratic Blocks of the British Isles presented at the Winnipeg Meeting, 1909 (Report B A, 1909, p 176), I reported the occurrence of a large boulder of tufa found by the side of a stream, the River Chater, at Launde, Leicestershire At the time I had no doubt the rock was an erratic

Since then Mr A J S Cannon has brought me a specimen of the same rock containing land-shells, which he informed me he had found *in situ* in the same locality Recognising the importance of this discovery I accompanied him later to examine the section, with the result that this rock was found in two different places a quarter of a mile apart

At the first point a section is exposed in the stream-side as follows —

		Ft	In
1	Soil	—	6
2	Chalky boulder clay, sand and gravel, with jurassic fossils, circa	2	
3	Calcareous tufa, with plants and land shells also *Pisidium* and entomostraca	-	6
4	Peat, with plant-remains and shells	1	
5	Tufa, similar to 3	—	6
6	Inclined Margaritatus Shales (Middle Lias)	3	--
		7	6

The disturbed character of the basal beds has no connection with beds 1 to 5, which are clearly undisturbed, and have not been inverted or thrown out of position since they were deposited

The importance of this section is evident, for with the exception of a deposit containing plants, annelids, crustacea, and mollusca at Aylestone in the Soar Valley in holocene deposits, and a similar fauna at Medbourne in the Welland Valley (not yet described), the Launde Section is the only ancient one so far discovered in Leicestershire

In the same district at Launde the tufa was found exposed in ditch-bottoms and rabbit-holes under superficial deposits, some 2,000 feet away The nearest sections of the same or later age are in Rutland at Apethorp, near Stamford, and at Casewick I have been favoured by Mr A S Kennard with specimens of the shells collected by J F. Bentley at Stamford, and described by Professor T R Jones, and there is a close similarity between such species as *Helix rotundata, Vitrea radiatula,* and *Carychium minimum,* which are the dominant shells at Launde There are more than twenty species of land and fresh-water shells, besides plants, that remain to be examined. No mammalian remains nor evidence of the activity of man in this locality have been found

SECTION D.—ZOOLOGY.

PRESIDENT OF THE SECTION.—P. CHALMERS MITCHELL, D.Sc., F.R.S.

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

Zoological Gardens and the Preservation of Fauna.

IN thinking over possible subjects for this Presidential Address, I was strongly tempted to enter on a discussion of the logical methods and concepts that we employ in Zoology. The temptation was specially strong to a Scot speaking in Scotland, that he should devote the hour when the prestige of the presidential chair secured him attention, to putting his audience right on logic and metaphysics. But I reflected that Zoology is doing very well, however its logic be wavering, and that as all lines subtend an equal angle at infinity, it would be of small moment if I were to postpone my remarks on metaphysics. And so I am to essay a more modest but a more urgent theme, and ask you to consider the danger that threatens the surviving land-fauna of this globe. A well-known example may serve to remind you how swift is the course of destruction. In 1867, when the British Association last met at Dundee, there were still millions of bison roaming over the prairies and forests of North America. In that year the building of the Union Pacific, the first great trans-continental railway, cut the herd in two. The Southern division, consisting itself of several million individuals, was wiped out between 1871 and 1874, and the practical destruction of the Northern herd was completed between 1880 and 1884. At present there are only two herds of wild bison in existence. In the Yellowstone Park only about twenty individuals remained in 1911, the greater part of the herd having been killed by poachers. A larger number, over three hundred, still survive near the Great Slave Lake, and there are probably nearly two thousand in captivity, in various Zoological Gardens, private domains and State Parks. It is only by the deliberate and conscious interference of man that the evil wrought by man has been arrested.

A second example that I may select is also taken from the continent of North America, but it is specially notable because it is sometimes urged, as in India, that migratory birds require no protection. Audubon relates that just a century ago Passenger Pigeons existed in countless millions, and that for four days at a time the sky was black with the stream of migration. The final extinction of this species has taken place since the last meeting of the Association in Dundee. In 1906 there were actually five single birds living, all of which had been bred in captivity, and I understand that these last survivors of a prolific species are now dead, although the birds ranged in countless numbers over a great continent.

It would be futile to discuss in detail the precise agencies by which the destruction of animal life is wrought, or the pretexts or excuses for them. The most potent factors are the perfection of the modern firearm and the enormous

increase in its use by civilised and barbarous man. Sometimes the pretext is sport, sometimes wanton destructiveness rules. The extermination of beasts-of-prey, the clearing of soil for stock or crops, the securing of meat, the commercial pursuit of hides and horns and of furs and feathers, all play their part. Farmers and settlers on the outskirts of civilisation accuse the natives, and allege that the problem would be solved were no firearms allowed to any but themselves. Sportsmen accuse other sportsmen, whom they declare to be no real sportsmen, and every person whose object is not sport. The great museums, in the name of science, and the rich amateur collectors press forward to secure the last specimens of moribund species.

But even apart from such deliberate and conscious agencies, the near presence of man is inhospitable to wild life. As he spreads over the earth, animals wither before him, driven from their haunts, deprived of their food, perishing from new diseases. It is part of a general biological process. From time to time, in the past history of the world, a species, favoured by some happy kink of structure or fortunate accident of adaptability, has become dominant. It has increased greatly in numbers, outrunning its natal bounds, and has radiated in every possible direction, conquering woodland and prairies, the hills and the plains, transcending barriers that had seemed impassable, and perhaps itself breaking up into new local races and varieties. It must be long since such a triumphant progress was unattended by death and destruction. When the first terrestrial animals crept out of their marshes into the clean air of the dry land, they had only plants and the avenging pressure of physical forces to overcome. But when the Amphibians were beaten by the Reptiles, and when from amongst the Reptiles some insignificant species acquired the prodigious possibility of transformation to Mammals, and still more when amongst the Mammals Eutherian succeeded Marsupial, Carnivore the Creodont, and Man the Ape, it could have been only after a fatal contest that the newcomers triumphed. The struggle, we must suppose, was at first most acute between animals and their nearest inferior allies, as similarity of needs brings about the keenest competition, but it must afterwards have been extended against lower and lower occupants of the coveted territory.

The human race has for long been the dominant terrestrial species, and man has a wider capacity for adaptation to different environments and an infinitely greater power of transcending geographical barriers than have been enjoyed by any other set of animals. For a considerable time many of the more primitive tribes, especially before the advent of firearms, had settled down into a kind of natural equilibrium with the local mammalian fauna, but these tribes have been first driven to a keener competition with the lower animals, and then, in most parts of the world, have themselves been forced almost or completely out of existence. The resourceful and aggressive higher races have now reached into the remotest parts of the earth and have become the exterminators. It must now be the work of the most intelligent and provident amongst us to arrest this course of destruction and to preserve what remains.

In Europe, unfortunately, there is little left sufficiently large and important to excite the imagination. There is the European bison, which has been extinct in Western Europe for many centuries, whilst the last was killed in East Prussia in 1755. There remains a herd of about seven hundred in the forests of Lithuania, strictly protected by the Tsar, whilst there are truly wild animals, in considerable numbers, in the Caucasus, small captive herds on the private estates of the Tsar, the Duke of Pless, and Count Potocki, and a few individuals in various Zoological Gardens. There is the beaver, formerly widespread in Europe, now one of the rarest of living mammals, and lingering in minute numbers in the Rhone, the Danube, in a few Russian rivers and in protected areas in Scandinavia. The wolf and the bear have shrunk to the recesses of thick forests and the remotest mountains, gluttons to the most barren regions of the north. The chamois survives by favour of game-laws and the vast inaccessible areas to which it can retreat, but the mouflon of Corsica and Sardinia and the ibex in Spain are on the verge of extinction. Every little creature, from the otter, wild cat and marten to the curious desman, is disappearing.

India contains the richest, the most varied, and, from many points of view, the most interesting part of the Asiatic fauna. Notwithstanding the teeming human population it has supported from time immemorial, the extent of its area, its dense forests and jungles, its magnificent series of river valleys, mountains,

and hills have preserved until recent times a fauna rich in individuals and species. The most casual glance at the volumes by sportsmen and naturalists written forty or fifty years ago reveals the delight and wonder of travel in India so comparatively recently as the time when the Association last met in Dundee. Sir H. H. Johnston has borne witness that even in 1895 a journey 'through almost any part of India was of absorbing interest to the naturalist' All is changed now, and there seems little doubt but that the devastation in the wonderful mammalian fauna has been wrought chiefly by British military officers and civilians, partly directly and partly by their encouragement of the sporting instincts of the Mohammedan population and the native regiments, although the clearing of forests and the draining of marshlands have played an important contributory part. The tiger has no chance against the modern rifle The one-horned rhinoceros has been nearly exterminated in Northern India and Assam. The magnificent gaur, one of the most splendid of living creatures, has been almost killed off throughout the limits of its range—Southern India and the Malay Peninsula Bears and wolves, wild dogs and leopards are persecuted remorselessly. Deer and antelope have been reduced to numbers that alarm even the most thoughtless sportsmen, and wild sheep and goats are being driven to the utmost limits of their range

When I speak of the fauna of Africa, I am always being reminded of the huge and pathless areas of the Dark Continent, and assured that lions and leopards, elephants and giraffe still exist in countless numbers, nor do I forget the dim recesses of the tropical forests where creatures still lurk of which we have only the vaguest rumour But we know that South Africa less than fifty years ago was a dream that surpassed the imagination of the most ardent hunter. And we know what it is now It is traversed by railways, it has been rolled over by the devastations of war The game that once covered the land in unnumbered millions is now either extinct, like the quagga and the black wildebeeste, or its scanty remnant lingers in a few reserves and on a few farms The sportsman and the hunter have been driven to other parts of the continent, and I have no confidence in the future of the African fauna The Mountains of the Moon are within range of a Long Vacation holiday Civilisation is eating into the land from every side All the great European countries are developing their African possessions There are exploring expeditions, punitive expeditions, shooting and collecting expeditions Railways are being pushed inland, water-routes opened up The land is being patrolled and policed and taxed, and the wild animals are suffering Let us go back for a moment to the Transvaal and consider what has happened since the Rand was opened, neglecting the reserves Lions are nearly extinct The hyæna has been trapped and shot and poisoned out of existence. The eland is extinct. The giraffe is extinct. The elephant is extinct The rhinoceros is extinct The buffalo is extinct The bontebok, the red hartebeeste, the mountain zebra, the oribi, and the grysbok are so rare as to be practically extinct And the same fate may at any time overtake the rest of Africa The white man has learned to live in the tropics, he is mastering tropical diseases, he has need of the vegetable and mineral wealth that lie awaiting him, and although there is yet time to save the African fauna, it is in imminent peril

When we turn to Australia, with its fauna of unique zoological interest, we come to a more advanced case of the same disease In 1909 Mr. G C. Shortridge, a very skilled collector, working for the British Museum, published in the 'Proceedings of the Zoological Society of London' the results of an investigation he had carried out on the fauna of Western Australia south of the tropics, during the years 1904-1907 He gave a map showing the present and comparatively recent distribution for each of the species of Marsupials and Monotremes indigenous to that locality West Australia as yet has been very much less affected by civilisation than Queensland, New South Wales or Victoria, and yet in practically every case there was found evidence of an enormous recent restriction of the range of the species Marsupials and Monotremes are, as you know, rather stupid animals, with small powers of adaptation to new conditions, and they are in the very gravest danger of complete extinction In the island of Tasmania, the thylacine, or marsupial wolf, and the Tasmanian devil have unfortunately incurred the just hostility of the stock raiser and poultry farmer, and the date of their final extermination is approaching at a pace that must be reckoned by months rather than by years

The development of the continent of North America has been one of the wonders of the history of the world, and we on this side of the Atlantic almost hold our breath as we try to realise the material wealth and splendour and the ardent intellectual and social progress that have turned the United States into an imperial nation. But we know what has happened to the American bison. We know the danger that threatens the pronghorn, one of the most isolated and interesting of living creatures, the Virginian deer, the mule-deer, and the bighorn sheep. Even in the wide recesses of Canada, the bighorn, the caribou, the elk, the wapiti, the white mountain goat, and the bears are being rapidly driven back by advancing civilisation. In South America less immediate danger seems to threaten the jaguar and maned wolf, the tapirs and ant eaters and sloths, but the energy of the rejuvenated Latin races points to a huge encroachment of civilisation on wild nature at no distant date.

You will understand that I am giving examples and not a catalogue even of threatened terrestrial mammals. I have said nothing of the aquatic carnivores, nothing of birds, or of reptiles, or of batrachians and fishes. And to us who are zoologists, the vast destruction of invertebrate life, the sweeping out, as forests are cleared and the soil tilled, of innumerable species that are not even named or described, is a real calamity. I do not wish to appeal to sentiment. Man is worth many sparrows; he is worth all the animal population of the globe, and if there were not room for both, the animals must go. I will pass no judgment on those who find the keenest pleasure of life in gratifying the primeval instinct of sport. I will admit that there is no better destiny for the lovely plumes of a rare bird than to enhance the beauty of a beautiful woman. I will accept the plea of those who prefer a well-established trinomial to a moribund species. But I do not admit the right of the present generation to careless indifference or to wanton destruction. Each generation is the guardian of the existing resources of the world; it has come into a great inheritance, but only as a trustee. We are learning to preserve the relics of early civilisations, and the rude remains of man's primitive arts and crafts. Every civilised nation spends great sums on painting and sculpture, on libraries and museums. Living animals are of older lineage, more perfect craftsmanship and greater beauty than any of the creations of man. And although we value the work of our forefathers, we do not doubt but that the generations yet unborn will produce their own artists and writers, who may equal or surpass the artists and writers of the past. But there is no resurrection or recovery of an extinct species, and it is not merely that here and there one species out of many is threatened, but that whole genera, families and orders are in danger.

Now let me turn to what is being done and what has been done for the preservation of fauna. I must begin by saying, and this was one of the principal reasons for selecting the subject of my Address, that we who are professional zoologists, systematists, anatomists, embryologists, and students of general biological problems, in this country at least, have not taken a sufficiently active part in the preservation of the realm of nature that provides the reason for our existence. The first and most practical step of world-wide importance was taken by a former President of the British Association, the late Lord Salisbury, one of the few in the long roll of English statesmen whose mind was attuned to science. In 1899 he arranged for a convention of the Great Powers interested in Africa to consider the preservation of what were curiously described as the 'Wild Animals, Birds and Fish' of that continent. The convention, which did most important pioneer work, included amongst its members another President of this Association, Sir Ray Lankester, whom we hold in high honour in this Section as the living zoologist who has taken the widest interest in every branch of zoology. But it was confined in its scope to creatures of economic or of sporting value. And from that time on the central authorities of the Great Powers and the local Administrators, particularly in the case of tropical possessions, seem to have been influenced in the framing of their rules and regulations chiefly by the idea of preserving valuable game animals. Defining the number of each kind of game that can be killed, charging comparatively high sums for shooting-permits, and the establishment of temporary or permanent reserved tracts in which the game may recuperate, have been the principal methods selected. On these lines, narrow although they are, much valuable work has been done, and the parts of the world where unrestricted shooting is still possible are rapidly being limited

I may take the proposed new Game Act of our Indian Empire, which has recently been explained, and to a certain extent criticised, in the 'Proceedings of the Zoological Society of London,' by Mr. E. P. Stebbing, an enlightened sportsman-naturalist, as an example of the efforts that are being made in this direction, and of their limitations.

The Act is to apply to all India, but much initiative is left to Local Governments as to the definition of the important words 'game' and 'large animal' The Act, however, declares what the words are to mean in the absence of such local definitions, and it is a fair assumption that local interpretations will not depart widely from the lead given by the central Authority. Game is to include the following in their wild state pigeons, sandgrouse, peafowl, jungle fowl, pheasants, partridges, quail, spurfowl, florican and their congeners, geese, ducks and their congeners, woodcock and snipe. So much for Birds Mammals include hares and 'large animals' defined as 'all kinds of rhinoceros, buffalo, bison, oxen; all kinds of sheep, goats, antelopes and their congeners, all kinds of gazelle and deer'

The Act does not affect the pursuit, capture, or killing of game by non commissioned officers or soldiers on whose behalf regulations have been made, or of any animal for which a reward may be claimed from Government, of any large animal in self-defence, or of any large animal by a cultivator or his servants whose crops it is injuring Nor does it affect anything done under licence for possessing arms and ammunition to protect crops, or for destroying dangerous animals under the Indian Arms Act Then follow prohibitory provisions all of which refer to the killing or to the sale or possession of game or fish, and provisions as to licences for sportsmen, the sums to be paid for which are merely nominal, but which carry restrictions as to the number of head that may be killed I need not enter upon detailed criticism as to the vagueness of this Act from the zoological point of view, or as to the very large loopholes which its provisions leave to civil and military sportsmen, these have been excellently set forth by Mr Stebbing, who has full knowledge of the special conditions which exist in India What I desire to point out is that it conceives of animals as game rather than as animals, and that it does not even contemplate the possibility of the protection of birds-of-prey and beasts-of-prey, and still less of the enormous numbers of species of animals that have no sporting or economic value.

Mr Stebbing's article also gives a list of the very large number of reserved areas in India, which are described as 'Game Sanctuaries' His explanation of them is as follows: 'With a view to affording a certain protection to animals of this kind (the elephant, rhinoceros, ruminants, &c) and of giving a rest to species which have been heavily thinned in a district by indiscriminate shooting in the past, or by anthrax, drought, &c, the idea of the Game Sanctuary was introduced into India (and into other parts of the world) and has been accepted in many parts of the country. The sanctuary consists of a block of country, either of forest or of grassland, &c, depending on the nature of the animal to which sanctuary is required to be given, the area has rough boundaries such as roads, fire lines, nullahs, &c, assigned to it, and no shooting of any kind is allowed in it, if it is a sanctuary pure and simple, or the shooting of carnivora may be permitted, or of these latter and of everything else save certain specified animals'

Mr Stebbing goes on to say that sanctuaries may be formed in two ways The area may be automatically closed and reopened for certain definite periods of years, or be closed until the head of game has become satisfactory, the shooting on the area being then regulated, and no further closing taking place, save for exceptional circumstances The number of such sanctuary blocks, both in British India and in the Native States, will cause surprise and pleasure to most readers, and it cannot be doubted but that they will have a large effect on the preservation of wild life The point, however, that I wish to make is that in the minds of those who have framed the Game Act, and of those who have caused the making of the sanctuaries—as indeed in the minds of their most competent critics—the dominant idea has been the husbanding of game animals, the securing for the future of sport for sportsmen I do not forget that there is individual protection for certain animals; no elephant, except a rogue elephant, may be shot in India, and there are excellent regulations regarding birds with plumage of economic value The fact remains that India, a country which still contains a considerable remnant of one of the richest faunas of the world, and which also is probably

more efficiently under the autocratic control of a highly educated body of permanent officials, central and local, than any other country in the world, has no provision for the protection of its fauna simply as animals

The conditions in Africa are very different from those in India The land is portioned out amongst many Powers The settled population is much less dense and the hold of the white settler and the white ruler is much less complete. The possibility of effective control of native hunters and of European travellers and sportsmen is much smaller, and as there are fewer sources of revenue, the temptation to exploit the game for the immediate development of the struggling colonies is much greater Still, the lesson of the extinction of the South African fauna is being taken to heart I have had the opportunity of going through the regulations made for the shooting of wild animals in Africa by this country, by our autonomic colonies, by France, Germany, Italy, Portugal, and Belgium, and, with the limitation that they are directed almost solely towards the protection of animals that can be regarded as game, they afford great promise for the future But this limitation is still stamped upon them, and even so enthusiastic a naturalist as Major Stevenson-Hamilton, the Warden of the Transvaal Government Game Reserves, who has advocated the substitution of the camera for the rifle, appears to be of the opinion that the platform of the convention of 1900 is sufficient It included the sparing of females and immature animals, the establishment of close seasons and game sanctuaries, the absolute protection of rare species, restrictions on the export for trading purposes of skins, horns and tusks, and the prohibition of pits, snares and game traps Certainly the rulers of Africa are seeing to the establishment of game reserves As for British Africa, there are two in Somaliland, two in the Sudan, two in Uganda and two in British East Africa (with separate reserves for eland, rhinoceros and hippopotamus), two in Nyasaland, three in the Transvaal, seven in Rhodesia, several in Natal and in Cape Colony, and at least four in Nigeria These are now administered by competent officials, who in addition are usually the executive officers of the game laws outside the reserved territory Here again, however, the preservation of game animals and of other animals of economic value and of a few named species is the fundamental idea In 1909 I had the honour of being a member of a deputation to the Secretary of State for the Colonies, arranged by the Society for the Preservation of the Wild Fauna of the Empire, one of the most active and successful bodies engaged in arousing public opinion on the subject Among the questions on which we were approaching Lord Crewe was that of changes in the locality of reserves Sometimes it had happened that for the convenience of settlers or because of railway extension, or for some other reason, proposals were made to open or clear the whole or part of a reserve When I suggested that the substitution of one piece of ground for another, even of equivalent area, might be satisfactory from the point of view of the preservation of large animals, but was not satisfactory from the zoological point of view, that in fact pieces of primeval land and primeval forest contained many small animals of different kinds which would be exterminated once and for all when the land was brought under cultivation, the point was obviously new not only to the Colonial Secretary, who very courteously noted it, but to my colleagues

This brings me to the general conclusion to which I wish to direct your attention and for which I hope to engage your sympathy We may safely leave the preservation of game animals, or rare species if these are well known and interesting, and of animals of economic value, to the awakened responsibility and the practical sense of the Governing Powers, stimulated as these are by the enthusiasm of special Societies Game laws, reserves where game may recuperate, close seasons, occasional prohibition and the real supervision of licence-holders are all doing their work effectively. But there remains something else to do, something which I think should interest zoologists particularly, and on which we should lead opinion There exist in all the great continents large tracts almost empty of resident population, which still contain vegetation almost undisturbed by the ravages of man, and which still harbour a multitude of small animals, and could afford space for the larger and better-known animals These tracts have not yet been brought under cultivation, and are rarely traversed except by the sportsman, the explorer and the prospector. On these there should be established, in all the characteristic faunistic areas, reservations which should not be merely temporary recuperating grounds for harassed game, but absolute

sanctuaries. Under no condition should they be open to the sportsman. No gun should be fired, no animal slaughtered or captured save by the direct authority of the wardens of the sanctuaries, and for the direct advantage of the denizens of the sanctuaries, for the removal of noxious individuals, the controlling of species that were increasing beyond reason, the extirpation of diseased or unhealthy animals The obvious examples are not the game reserves of the Old World, but the National Parks of the New World and of Australasia. In the United States, for instance, there are now the Yellowstone National Park with over two million acres, the Yosemite in California with nearly a million acres, the Grand Cañon Game Preserve with two million acres, the Mount Olympus National Monument in Washington with over half a million acres, and the Superior Game and Forest Preserve with nearly a million acres, as well as a number of smaller reserves for special purposes, and a chain of coastal areas all round the shores for the preservation of birds In Canada, in Alberta, there are the Rocky Mountains Park, the Yoho Park, Glacier Park, and Jasper Park, together extending to over nine million acres, whilst in British Columbia there are smaller sanctuaries. These, so far as laws can make them, are inalienable and inviolable sanctuaries for wild animals We ought to have similar sanctuaries in every country of the world, national parks secured for all time against all the changes and chances of the nations by international agreement In the older and more settled countries the areas selected unfortunately must be determined by various considerations, of which faunistic value cannot be the most important But certainly in Africa, and in large parts of Asia, it would still be possible that they should be selected in the first place for their faunistic value The scheme for them should be drawn up by an international commission of experts in the geographical distribution of animals, and the winter and summer haunts of migratory birds should be taken into consideration It is for zoologists to lead the way, by laying down what is required to preserve for all time the most representative and most complete series of surviving species without any reference to the extrinsic value of the animals And it then will be the duty of the nations, jointly and severally, to arrange that the requirements laid down by the experts shall be complied with

And now I come to the last side of my subject, that of Zoological Gardens, with which I have been specially connected in the last ten years My friend M Gustave Loisel, in his recently issued monumental 'Histoire des Ménageries,' has shown that in the oldest civilisations of which we have record, thousands of years before the Christian Era, wild animals were kept in captivity He is inclined to trace the origin of the custom to a kind of totemism Amongst the ancient Egyptians, for instance, besides the bull and the serpent, baboons, hippopotami, cats, lions, wolves, ichneumons, shrews, wild goats and wild sheep, and, of lower animals, crocodiles, various fishes and beetles were held sacred in different towns. These animals were protected, and even the involuntary killing of any of them was punished by the death of the slayer; but besides this general protection, the priests selected individuals which they recognised by infallible signs as being the divine animals, and tamed, guarded and fed them in the sacred buildings, whilst the revenues derived from certain tracts of land were set apart for their support The Egyptians were also famous hunters and kept and tamed various wild animals, including cheetahs, striped hyænas, leopards, and even lions, which they used in stalking their prey The tame lions were sometimes clipped, as in ancient Assyria, and used both in the chase and in war The rich Egyptians of Memphis had large parks in which they kept not only the domestic animals we now know, but troops of gazelles, antelopes, and cranes which were certainly tame and were herded by keepers with wands. So also in China, at least fifteen centuries before our era, wild animals were captured in the far north by the orders of the Emperor and were kept in the Royal Parks A few centuries later the Emperor Wen-Wang established a zoological collection between Pekin and Nankin, his design being partly educational, as it was called the Park of Intelligence In the valley of the Euphrates, centuries before the time of Moses, there were lists of sacred animals, and records of the keeping in captivity of apes, elephants, rhinoceroses, camels and dromedaries, gazelles and antelopes, and it may well be that the legend of the Garden of Eden is a memory of the Royal Menagerie of some ancient king. The Greeks, whose richest men had none of the wealth of the Egyptians or of the princes of the East, do not appear to have kept many wild animals, but the magnates of imperial Rome captured large

numbers of leopards, lions, bears, elephants, antelopes, giraffes, camels, rhinoceroses and hippopotami, and ostriches and crocodiles, and kept them in captivity, partly for use in the arena, and partly as a display of the pomp and power of wealth. In later times royal persons and territorial nobles frequently kept menageries of wild animals, aviaries and aquaria, but all of these have long since vanished

Thus, although the taste for keeping wild animals in captivity dates from the remotest antiquity, all the modern collections are of comparatively recent origin, the oldest being the Imperial Menagerie of the palace of Schonbrunn, Vienna, which was founded about 1752, whilst some of the most important are only a few years old. These existing collections are of two kinds A few are the private property of wealthy landowners, and their public importance is due partly to the opportunity they have afforded for experiments in acclimatisation on an extensive scale, and still more to the refuge they have given to the relics of decaying species The European bison is one of the best-known cases of such preservation, but a still more extraordinary instance is that of Père David's deer, a curious and isolated type which was known only in captivity in the Imperial Parks of China The last examples in China were killed in the Boxer war, and the species would be absolutely extinct but for the small herd maintained by the Duke of Bedford at Woburn Abbey In 1909 this herd consisted of only twenty-eight individuals, it now numbers sixty-seven The second and best-known types of collections of living animals are in the public Zoological Gardens and Parks maintained by Societies, private companies, States and municipalities There are now more than a hundred of these in existence, of which twenty-eight are in the United States, twenty in the German Empire, five in England, one in Ireland, and none in Scotland But perhaps I may be allowed to say how much I hope that the efforts of the Zoological Society of Scotland will be successful, and that before many months are over there will be a Zoological Park in the capital of Scotland There is no reason of situation or of climate which can be urged against it The smoke and fog of London are much more baleful to animals than the east winds of Edinburgh The Gardens of North Germany and the excellent institution at Copenhagen have to endure winters much more severe than those of lowland Scotland, whilst the arctic winter and tropical summer of New York form a peculiarly unfortunate combination, and none the less the Bronx Park at New York is one of the most delightful menageries in existence The Zoological Society of Scotland will have the great advantage of beginning where other institutions have left off, it will be able to profit by the experience and avoid the mistakes of others The Zoological Society of London would welcome the establishment of a menagerie in Scotland, for scientific and practical reasons As I am speaking in Scotland, I may mention two of the practical reasons The first is that in Great Britain we labour under a serious disadvantage as compared with Germany with regard to the importation of rare animals When a dealer in the tropics has rare animals to dispose of, he must send them to the best market, for dealing in wild animals is a risky branch of commerce If he send them to this country, there are very few possible buyers, and it often happens that he is unable to find a purchaser If he send them to Germany, one or other of the twenty Gardens is almost certain to absorb them, and failing Germany, Belgium and Holland are near at hand Were there twenty prosperous Zoological Gardens in Great Britain, they could be better stocked, at cheaper rates, than those we have now The second practical reason is that it is a great advantage to menageries to have easy opportunities of lending and exchanging animals, for it often happens that as a result of successful breeding, or of gifts on the one hand or of deaths on the other, a particular institution is overstocked with one species or deficient in another

One of the ideas strongly in the minds of those who founded the earlier of modern Zoological Gardens was the introduction and acclimatisation of exotic animals that might have an economic value It is curious how completely this idea has been abandoned and how infertile it has proved The living world would seem to offer an almost unlimited range of creatures which might be turned to the profit of man and as domesticated animals supply some of his wants And yet I do not know of any important addition to domesticated animals since the remotest antiquity A few birds for the coverts, fancy water-fowl for ponds and lakes, and brightly plumaged birds for cages or for aviaries have been

introduced, chiefly through Zoological Societies, but we must seek other reasons for their existence than these exiguous gains

Menageries are useful in the first place as educational institutions, in the widest sense of the word Every new generation should have an opportunity of seeing the wonder and variety of animated nature, and of learning something that they cannot acquire from books or pictures or lectures about the chief types of wild animals For that reason Zoological Gardens should be associated in some form with elementary and secondary education. We in London admit the children from elementary schools on five mornings in the week at the nominal charge of a penny for each child, and, in co-operation with the Educational Committee of the London County Council, we conduct courses of lectures and demonstrations for the teachers who will afterwards bring their children to visit the Gardens

Menageries provide one of the best schools for students of art, for nowhere else than amongst living animals are to be found such strange fantasies of colour, such play of light on contour and surface, such intricate and beautiful harmonies of function and structure To encourage art the London Society allows students of recognised schools of drawing and painting, modelling and designing, to use the Gardens at nominal rates

Menageries provide a rich material for the anatomist, histologist, physiologist, parasitologist and pathologist It is surprising to note how many of the animals used by Lamarck and Cuvier, Johannes Muller and Wiedersheim, Owen and Huxley were obtained from Zoological Gardens At all the more important Gardens increasing use is being made of the material for the older purposes of anatomical research and for the newer purposes of pathology and physiology

There remains the fundamental reason for the existence of menageries, that they are collections of living animals and therefore an essential material for the study of zoology Systematic zoology, comparative anatomy, and even morphology, the latter the most fascinating of all the attempts of the human intellect to re-create nature within the categories of the human mind, have their reason and their justification in the existence of living animals under conditions in which we can observe them And this leads me to a remark which ought to be a truism but which, unfortunately, is still far from being a truism The essential difference between a zoological museum and a menagerie is that in the latter the animals are alive The former takes its value from its completeness, from the number of rare species of which it has examples, and from the extent to which its collections are properly classified and arranged The value of a menagerie is not its zoological completeness, not the number of rare animals that at any moment it may contain, not even the extent to which it is duly labelled and systematically arranged, but the success with which it displays its inhabitants as living creatures under conditions in which they can exercise at least some of their vital activities.

The old ideal of a long series of dens or cages in which representatives of kindred species could mope opposite their labels is surely but slowly disappearing It is a museum arrangement, and not an arrangement for living animals The old ideal by which the energy and the funds of a menagerie were devoted in the first place to obtaining species 'new to the collection' or 'new to science' is surely but slowly disappearing It is the instinct of a collector, the craving of a systematist, but is misplaced in those who have the charge of living animals Certainly we like to have many species, to have rare species, and even to have new species represented in our menageries But what we are learning to like most of all is to have the examples of the species we possess, whether these be new or old, housed in such a way that they can live long, and live happily, and live under conditions in which their natural habits, instincts, movements, and routine of life can be studied by the naturalist and enjoyed by the lover of animals

Slowly the new conditions are creeping in, most slowly in the older institutions hampered by lack of space, cumbered with old and costly buildings, oppressed by the habits of long years and the traditions established by men who none the less are justly famous in the history of zoological science Space, open air, scrupulous attention to hygiene and diet, the provision of some attempt at natural environment are receiving attention that they have never received before You will see the signs of the change in Washington and New York, in London and Berlin, in Antwerp and Rotterdam, and in all the Gardens of Germany. It was

begun simultaneously, or at least independently, in many places and under the inspiration of many men. It is, I think, part of a general process in which civilised man is replacing the old hard curiosity about nature by an attempt at sympathetic comprehension We no longer think of ourselves as alien from the rest of nature, using our lordship over it for our own advantage, we recognise ourselves as part of nature, and by acknowledging our kinship we are on the surest road to an intelligent mastery But I must mention one name, that of Carl Hagenbeck of Hamburg, to be held in high honour by all zoologists and naturalists, although he was not the pioneer, for the open-air treatment and rational display of wild animals in captivity were being begun in many parts of the world while the Thier-Park at Stellingen was still a suburban waste He has brought a reckless enthusiasm, a vast practical knowledge and a sympathetic imagination to bear on the treatment of living animals, and it would be equally ungenerous and foolish to fail to recognise the widespread and beneficent influence of his example.

However we improve the older menageries and however numerous and well-arranged the new menageries may be, they must always fall short of the conditions of nature, and here I find another reason for the making of zoological sanctuaries throughout the world If these be devised for the preservation of animals, not merely for the recuperation of game, if they be kept sacred from gun or rifle, they will become the real Zoological Gardens of the future, in which our children and our children's children will have the opportunity of studying wild animals under natural conditions I myself have so great a belief in the capacity of wild animals for learning to have confidence in man, or rather, for losing the fear of him that they have been forced to acquire, that I think that man, innocent of the intent to kill, will be able to penetrate fearlessly into the sanctuaries, with camera and notebook and field-glass In any event all that the guardians of the future will have to do will be to reverse the conditions of our existing menageries and to provide secure enclosures for the visitors instead of for the animals

I must end as I began this Address by pleading the urgency of the questions I have been submitting to you as an excuse for diverting your attention to a branch of zoology which is alien from the ordinary avocations of most zoologists, but which none the less is entitled to their fullest support. Again let me say to you that I do not wish to appeal to sentiment, I am of the old school, and, believing that animals are subject and inferior to man, I set no limits to human usufruct of the animal kingdom But we are zoologists here, and zoology is the science of the living thing We must use all avenues to knowledge of life, studying the range of form in systematic museums, form itself in laboratories, and the living animal in sanctuaries and menageries And we must keep all avenues to knowledge open for our successors, as we cannot guess what questions they may have to put to nature

---

The following Papers were then read —

1 *Biological Science and the Pearling Industry*
By H LYSTER JAMESON, *M A*, *D Sc*, *Ph D*

The paper consisted of a review of the scientific work that has been done up to the present with a view to rendering the pearl and mother-of-pearl producing industries more profitable

The Japanese pearl-farming enterprise, inaugurated under the guidance of the late Professor Mitsukuri, the real pioneer of modern work in the application of biological knowledge to this industry, is concerned with conserving and cultivating the little Japanese pearl oyster, a close ally of the Ceylon species, and with causing it to produce pearly excrescences or 'blisters,' which are known in the trade as 'Culture Pearls.' These culture pearls are produced by a method analogous to that which has been known to the Chinese for ages, and to that invented by Linnæus. The Japanese culture pearl industry is now an old-established one, giving employment to a great number of people, and Japanese culture pearls are well-known objects in European jewellery

The Japanese industry is the only instance, known to the author, of the

application of biological knowledge and theory to the improvement of this industry that has proved an unquestionable business success

Attempts have been made, and are being made, to cultivate *Margaritifera margaritifera*, var *mazatlanica*, in Lower California, on lines somewhat analogous to those followed in European oyster culture

There have been several scientific missions to Tahiti and the Gambier Islands with a view to formulating plans for improving the mother-of-pearl fisheries, but these missions have so far not yielded commercial results, though considerable advance has been made in our knowledge of the species concerned—*Margaritifera margaritifera*, var *cumingii*

The work of the several investigators who studied the Australian mother-of-pearl oyster, *Margaritifera maxima*, foremost among whom is the late Mr Saville Kent, was then briefly reviewed, and the particular problems of the Australian mother-of-pearl fishery described The problems in Australia centre mainly around the impossibility, up to the present, of obtaining the freshly attached spat in sufficient quantities for cultivation, and the difficulty of distinguishing it when found from the young of two or three valueless species, the spat of which can be collected in vast quantities Every investigator has been taken in by this false or 'bastard' spat, including Saville Kent, by whom it was figured as the young of *M maxima* An explanation is suggested of the causes of the failure of an attempt to cultivate mother-of-pearl oysters, and to produce pearls, on lines laid down by Mr Saville Kent, in Queensland Here it would appear that, besides being misled by the false spat into unfounded hopes of success in cultivation, some confusion of ideas existed as to the distinction between pearls and blisters In the author's opinion this confusion probably led to the experiments in pearl production being carried on on comparatively unfruitful lines, based on the theory, which the author is unable to support (unless perhaps in a very small number of instances), that pearls are comparable in their mode of origin to blisters produced by mechanical stimulation

The recent work of Mr T H Haynes in North-west Australia was discussed It was suggested that this enterprise suffered through lack of skilled scientific assistance Here an elaborate attempt was made to breed mother-of pearl oysters in a specially constructed pond, without the assistance of anyone who had that experience of embryology and of the free-swimming stages of larval invertebrates which only a modern biological training followed by highly specialised research could give

The paper then went on to give an account of the scientific work done on the Ceylon pearl fisheries during the past ten years, and to discuss the causes which have led to the failure of biological science to yield such results as were foreshadowed by experts, and expected by the Government and the promoters of the Ceylon Company of Pearl Fishers, now in liquidation To this end the circumstances under which the work was inaugurated were recalled, and the work of Professor Herdman and his successors discussed, more particularly with regard to the author's recent work on Ceylon Pearls ('P Z S,' 1912, pp 260 358) in which he disputes the Cestode theory of pearl production Attention was drawn to the attitudes of the scientific and popular press, and of the 'business man,' with regard to these Ceylon investigations Thus 'Nature' (July 18, 1907, pp 271-2) definitely claims, as attributable to Professor Herdman's scientific investigations, the success of the fisheries of 1903, 1904, 1905, and 1906, though the author believes this was never claimed (and indeed could not have been claimed) by Professor Herdman himself On the other hand, the popular press, and the business man as represented by the directors and shareholders of the company, were perhaps hardly just in their sweeping assertions as to the failure of science or scientists

Consideration of these points led the author to ask, as a question that might well exercise the attention of those interested in the organisation of biological science in England, whether England, or rather the Empire, possesses the most efficient machinery for dealing with matters of such a kind as new and difficult problems of economic biology, referred by Governments or others for expert advice Whether, in fact, we do not require—especially in view of the minute specialisation which modern progress demands, and of the consequent impossibility of the ordinary man keeping pace with developments, except in a

limited field—some organising or co-ordinating machinery that will bring to bear on a question like this all available reputable specialist opinion that is likely to be useful, both in the preliminary stages when a plan of campaign is to be formulated, and in the latter phases when examination, criticism, correlation of results, and the formulation of a working policy are required

It is suggested that if such machinery existed not only would the prospects of such missions as the Ceylon one, undertaken under the support of a powerful Government, and backed at a later stage by strong financiers, be brighter, and the mistakes which have unquestionably been made in this case be practically impossible, but the public would soon begin to realise that there were available expert 'courts of appeal' to protect the investor from the too hastily formed schemes of enthusiastic scientists, or from the promoter posing before the layman as a scientific expert.

2 *Note on an Hermaphrodite Amphioxus*

By E S Goodrich, *F R S*

A single hermaphrodite specimen of *Amphioxus lanceolatus* was found at Naples in the summer of 1911 It is an adult ripe male with twenty-five gonads on each side All these are typical testes containing spermatozoa only, with the exception of the ninth gonadial sac on the left side, which contains ova only, and is in the form of a typical ovary This appears to be the only instance of hermaphroditism yet described in the Cephalochordata

3 *On Scottish Sea-fisheries*, 1898-1912

By Professor W C McIntosh, *F R S*

When the British Association last met in Dundee (1867) the scientific study of the marine fisheries had not begun, though considerable attention had been devoted to the life-history of the salmon Indeed, it was sixteen or seventeen years later before a commencement was made with this important subject—under the auspices of Lord Dalhousie, the Chairman of the Royal Commission on Trawling and the Fisheries (1883-85) This Commission was appointed in response to urgent appeals in regard to the supposed decadence of the sea-fisheries in general The subject has already been dealt with in its earlier aspects in a communication to the Edinburgh Meeting of the British Association in 1892 (viz, 'A Brief Sketch of the Scottish Fisheries, chiefly in their Scientific Aspects during the past decade, 1882-1892'), in the 'Resources of the Sea' in 1898, and in 1903 (a second decade) after the international scheme of work had been outlined Two lectures were also given at the Royal Institution in May 1907 ('Zoologist' and 'Nature') The object of the present communication is to carry the subject up to date, and to consider what conclusions may safely be drawn from a review of the whole question

In the 'Resources of the Sea' an abstract of the yearly captures by liners and trawlers up to 1897 (inclusive) was entered, and, for the sake of continuity, a similar abstract is given up to 1911, so that the yearly fluctuations may be observed and explanatory remarks made where necessary Without going into detail in this abstract, it will be seen how steadily the yield of the fisheries has advanced, so that within a period of twenty-five years the amount has been nearly doubled Yet in the case of the white fishes the period mentioned has seen the gradual diminution of the captures of the liners almost to half the amount The increase of the captures by net, however, within the same period have been nearly doubled, so it may be that greater attention is paid by the liners to the herring fishery than to the white fishing. During the twenty-five years, on the other hand, the captures by trawlers have increased no less than sixfold, and appear to be still increasing, whilst their entrance into competition with the liners in the capture of herrings, so long solely in the hands of the liners may conduce to further changes

A careful perusal of the annual statistics of the Fishery Board for Scotland, of the statistical bulletin of the International Bureau for the North Sea, as well

as observations on fisheries in general, do not lead to pessimistic views on the subject. Such a perusal, indeed, bears out the propriety both of the caution exercised in recommending closures in 1884, and the deductions made in 1898 in the 'Resources of the Sea,' so far as the safety of the food-fishes is concerned.

Within the experience of one life not a few of the important food-fishes have been the subject of gloomy forebodings to the fishing community, and especially to those who have emphasised their views. The herring, the cod, the haddock, the plaice, the lemon-dab, the sole, and the turbot have each in turn occupied this position. Yet after all these years is any one of these on the road to extinction—or even to a serious diminution when the respective efforts to capture are taken into consideration? It is but a slender argument, for example, to point to the statistical diminution of the plaice in a single rich bay within recent years, without taking cognisance of the fact that in the first brush of uninterrupted fishing, or with the novelty of the nets, the men used all their energies and every art to capture, whereas recently many follow less hardy and strenuous pursuits in addition to casual fishing. Instead of increased exertion in the keen competition it is sufficient for some to assert that the trawlers outside the limit have swept off all the fishes. Fishing needs much time and all the energies of the fine, hardy men in whom the country rightly takes a deep interest, and successful fishing in certain cases likewise needs freedom from agitation and the rousing of class prejudices. Some, indeed, hold that crofting and fishing are incompatible with success in either, and there may be a basis of truth in this view. At any rate, it is not reasonable to place weight on the reduction in captures of any fish without an inquiry into the persistence of the methods.

In connection with the supposed diminution of the food fishes of the sea, notice on the present occasion can only be taken of the plaice, which for years has been a source of frequent solicitude. It is known that a limited area, under certain conditions, may be denuded of its large plaice, but this does not imply the serious diminution of the species, for it is so widely dispersed over the North Sea as to be favourably placed for survival. The gaps made by the removal of the large forms are by-and-by filled by the smaller, which on almost every sandy beach swarm in vast multitudes. So long as this continues the plaice is comparatively safe. Besides, it is well to remember that Nature is able to supply the whole of the common eels of the western border of Europe and of the Mediterranean from eggs shed in mid-Atlantic, as Dr. Johs. Schmidt has recently so graphically told. Compared with this remarkable condition, it is but a simple problem for the plaice to hold its own—scattered as the adults are over the North Sea, spawning so near our shores, and the eggs, larvæ, and young in countless multitude on every suitable site. Further, as if to impress the lesson, there is the instance of the estuary of the Thames, where for hundreds of years a vast destruction of young soles by the shrimpers has taken place daily, and yet the adults have not been extirpated.

---

4. *The Survey of the Freshwater Fauna of the Indian Empire now being carried out by the Indian Museum.* By NELSON ANNANDALE, *D.Sc., F.A.S.B.*

About forty years ago the late Mr. J. Wood-Mason began to collect in Calcutta the decapod crustacea of Indian and Burmese rivers, lakes, and ponds with a view to the preparation of a monograph. Although he only published a few short papers on the crabs, his collection proved of the utmost value to Colonel Alcock in his account of Potomonidæ (1910) in the 'Catalogue of Indian Decapod Crustacea in the collection of the Indian Museum.' Indeed, it may now be said that India is the only tropical country in which the freshwater crabs have been worked out on a satisfactory system. About six years ago I became specially interested in the fauna of certain pools of brackish water in the delta of the Ganges which had been visited soon after their formation in the middle of the nineteenth century by the late Dr. F. Stoliczka, and had provided him with the subject for a paper of great interest on an Actinian and a Polyzoon he found in them. It soon became evident, however, that to obtain material for a proper comparison of the estuarine fauna of the Ganges with the freshwater

fauna of Bengal and other parts of the Indian Empire, it would be necessary to undertake a survey of the latter A little later a substantial increase in the scientific staff of the Indian Museum made it possible greatly to extend our activities, and, almost insensibly, a survey of the kind has actually commenced, Colonel Alcock's work on the Decapoda forming an excellent standard and basis for comparison. In one point we have even attempted to improve upon that standard, namely, in paying very particular attention to the bionomics of the animals described With the zealous co operation of numerous correspondents in different parts of the country, and more especially of the Assistant Superintendents of the Museum, Messrs Stanley Kemp, B L Chaudhuri, and F H Gravely, of our honorary assistants, Captain Seymour Sewell and Mr T Southwell, and of Mr E Brunetti, the work is now proceeding apace Already an account of the sponges, polyzoa, and hydroids has been published in the 'Fauna of British India,' and the Indian representatives of several of the smaller groups have been discussed in the 'Records of the Indian Museum' Mr Kemp has commenced a detailed account of the Decapoda Macrura, and Mr Chaudhuri a revision of the fish of Northern India, while Mr Gravely hopes shortly to describe the interesting flat-worms of the group Temnocephaloidea Among the most interesting specific discoveries already made in connection with the survey are those of an Indian freshwater medusa of the genus *Limnocnida*, a new type of Temnocephaloidea allied to the European *Scutariella*, a Rhizocephalon from the hills of the Andaman Islands, a species of *Xiphocaridina* (Atyidæ) hitherto only known from New Zealand and the Chatham Islands, several interesting aquatic oligochætes, and a considerable number of new species of fish

Lantern slides of some of the more interesting types were shown

---

5 *The Plankton of Lough Neagh, Ireland*
By W J DAKIN, *D Sc , F L S , and* M LATARCHE, *M Sc*

The following is a brief account of a few interesting results of a somewhat prolonged study of the Lough Neagh plankton The research was commenced in 1910, and was aided by grants from the Royal Society and the Royal Irish Academy The complete Paper will appear shortly in the 'Transactions of the Royal Irish Academy.' The investigation extended over a year, and during this time catches were made quantitatively at regular intervals It is therefore the first quantitative fresh-water plankton investigation to be made in the British Islands, and the first detailed zoo-plankton investigation of any kind to be carried out over a long period in a British lake

The water of Lough Neagh is extremely rich in plankton, and a comparison with the Irish Sea shows that there is far less plankton present in the latter, taking the quantity for the whole year in both cases, and an equal volume of water The conditions, on the whole, differ greatly from those observed during Sir J Murray's investigations of the Scottish lochs, and the researches of the Messrs West on English lakes As a matter of fact, the Danish lakes resemble much more closely Lough Neagh in the character of the plankton present Both the phyto-plankton and the zoo-plankton of Lough Neagh are made up of Arctic and Central European species existing side by side The distribution records are perhaps amongst the most valuable and interesting of the results

The authors cannot accept the Wesenberg Lund-Ostwald theory that seasonal variations in planktonic organisms are due wholly to changes in the viscosity of the water. The changes observed in the plankton species of Lough Neagh are of the usual two kinds, form and size. The Wesenberg Lund-Ostwald hypothesis assumes that a reduction in size takes place in the summer months, so that by a relative increase in superficial area the organisms can still remain buoyant though the viscosity of the water has decreased. Similarly, spines or other excrescences will be developed when the water is most warm The authors consider that —

(1) It is characteristic of organisms of colder waters to be larger, whether planktonic or benthic and fixed.

(2) The seasonal variation is more likely determined by other factors—as experimentally shown by Woltereck—and in some cases this variation *merely*

coincides with that necessary for the support of the Wesenberg Lund-Ostwald theory.

(3) There is no advantage to be gained by a planktonic animal whose specific gravity is greater than water increasing its superficial area during times of reduced viscosity. These points were explained at greater length in the Paper

FRIDAY, SEPTEMBER 6

The following Papers and Reports were read —

1. *The Specific Histological Characters of the 'Luminous Cells' of* Pyrosoma giganteum *and of* Cyclosalpa pinnata *By* Professor CH JULIN.

In a recent publication[1] I demonstrated the following facts (1) The cells of the test (internal follicular cells of Kowalevsky, kalymmocytes of Salensky) of the egg of *Pyrosoma giganteum* persist throughout the whole of the development At each of the principal resting-phases in the embryogeny, they show a characteristic topographical rearrangement in the egg This rearrangement, this varying localisation, which I demonstrated for the first time, depends especially, at each of these stages, upon the abundant formation of these cells in distinct regions of the follicular epithelium of the egg (2) The test-cells of the egg of *Pyrosoma* become exclusively and directly the cells of the paired luminous organs of the four ascidiozoids of the first young tetrazoid colony This last and definitive localisation of the test-cells takes place during the last resting-phase of embryogeny (3) Like the cells of the luminous organs of the primary and secondary ascidiozoids, the test cells of the egg of *Pyrosoma* are luminous, and it is probable that this specific physiological property is correlated with the specific histological characters which these cellular elements possess in common These test-cells may, therefore, as correctly be termed 'luminous or light-producing cells,' as much as the cells of the luminous organs of the ascidiozoids (4) The specific histological characters common to both test-cells and the cells of the luminous organs of the ascidiozoids (both primary and secondary) of *Pyrosoma* consist essentially in the presence of a closely convoluted tube in the cell-bodies, the wall of which is distinctly achromophile, and which is traversed by an achromophile reticulum, the meshes of which are filled with an albuminous liquid On the reticular knots, and in immediate relation to this liquid, are *numerous powdery granulations of nuclein*, an albuminous substance rich in phosphorus This tube is entirely immersed in a small amount of liquid which fills the remainder of the cell-space

The results, both histological and experimental, obtained in the case of *Pyrosoma*, led me to examine whether such cells were present in the *lateral organs* of *Cyclosalpa pinnata*, which, as is known, are luminous

Very briefly, the results which I have obtained are as follows The luminous lateral organs of both the solitary form of *Cyclosalpa pinnata* of the colonial form differ in structure from the luminous organs of the ascidiozoids of *Pyrosoma* In the latter each luminous organ consists entirely of a mass of luminous cells quite free and independent of one another, immersed in the peripharyngeal blood sinus (*pericoronary sinus*) The cells are devoid of all nervous connection In *Cyclosalpa pinnata*, agreeing with the description given by Fernandez, each lateral organ has its own framework of connecting cells, the freely-communicating meshes being filled with free blood-cells, the shape, form, and structure of which are very variable Moreover, these cells, of which there is a considerable number, the specific character of which had not been recognised by Fernandez, have the distinctive character of the test-cells of the egg, and of the luminous cells of the ascidiozoids of *Pyrosoma* They are, however, smaller than the latter. In the substance of the cell lies a tube, sometimes continuous, more frequently discontinuous, having numerous compact convolutions. When

[1] *Zoolog. Jahrbücher*, Suppl. xv. 1 Bd. 1912, p. 775.

discontinuous it has the appearance of angular vesicles The wall of the tube is less distinctly achromophile than in the luminous cells of *Pyrosoma* It, too, is traversed by an achromophile reticulum in which are scattered many nuclein granules This tube is also embedded in a scanty amount of liquid which fills the remainder of the cell space

Analogy with the conditions found in *Pyrosoma*, in which the distinctive cells are manifestly the only luminescent elements, affords justification for concluding that it is extremely probable that the cells in *Cyclosalpa pinnata* which contain an intracellular tube, with the very distinctive histological characters just mentioned, are luminous cells Nevertheless, while these elements compose the entire cellular structure of the luminous organs of *Pyrosoma*, in *Cyclosalpa* blood-cells in every stage of development are also to be found in the lateral organs These organs in *C pinnata* play the double rôle of being both luminous and hœmopoietic. In *P giganteum*, these two functions are carried out by different organs light-production by the luminous organs of Panceri, which are situated symmetrically at the anterior or oral end of the pharynx in the pericoronary sinus, the hœmopoietic function by the dorsal organ (dorsal gland of authors) which, originally double and bilaterally symmetrical, becomes subsequently single and median, and situated in the dorsal sinus of the branchial sac

It would be interesting to ascertain whether the luminous cells of the lateral organs of the solitary form of *Cyclosalpa* are derived from the cell of the test of the egg, as is the case of the cells of the luminous organs of the four ascidiozoids

Without awaiting further results, it seems to be of sufficient interest to draw attention to the distinctive structure common to the luminous cells of *Pyrosoma* on the one hand, and to those cells which I believe to be the luminescent elements of the lateral organs of *Cyclosalpa* on the other

2 *On the Life History of* Echinocardium cordatum *By* Professor E W MacBride, *LL D , F R S*

The results which this Paper recorded were obtained during a sojourn at the Biological Station of the West of Scotland Marine Biological Association at Millport last summer

Of the development of Spatangoidea very little was previously known Spatangoid larvæ were described by Johannes Muller, and in particular the fully grown larva of *Echinocardium cordatum* was described by Mortensen The earliest stages of the development of this larva have been described by Ziegler, who reared them from the egg. Owing to the fact that I had at my disposal a rich culture of the diatom Nitschia, I was enabled to rear the eggs from the moment of fertilisation throughout their entire larval history until they metamorphosed into young Spatangoids This stage in their development was reached at a period of from eighteen to twenty-three days after fertilisation

The egg segments rapidly and forms a blastula which is ellipsoidal, not spherical this blastula ruptures the egg membrane and rises to the top as a free-swimming larva twelve to eighteen hours after fertilisation About ten hours later it has become converted into a gastrula, an invagination having taken place at one pole. There is an anterior tuft of specially long cilia The skeleton appears in the typical manner as two calcareous 'asters,' situated right and left of the archenteron. By the outgrowth of specially long branches of these the formation of the postoral larval arms is initiated The rods supporting these arms are latticed The cœlom arises as an unpaired vesicle which is nipped off from the apex of the archenteron, and which then becomes divided into right and left halves At the same time the stomodæum makes its appearance as a wide shallow pit which grows towards and meets the apex of the archenteron, and thus the alimentary canal is completed. The ciliated cells become restricted to a single loop, and the anterior tuft of cilia is incorporated in this, finding its place in the præoral portion of the loop The antero-lateral arms grow out, supported by antero-lateral rods. At the aboral pole of the larva there is a mass of mesenchyme cells, in which are embedded the distal ends of the body rods and the ends of the recurrent rods—these last-named being branches running back from the antero-lateral rods In the midst of this mesenchyme an independent calcareous

aster appears, which forms the skeleton for the club-shaped aboral spike which now grows out This skeleton consists of a lattice of three diverging rods with cross-connections. The apex of the club is covered with a pad of thickened epithelium carrying cilia. The base of the club skeleton forms connections with the body and recurrent rods So far as I can make out, both right and left cœlomic vesicles send up prolongations which become madreporic pore-canals, and open to the exterior by right and left madreporic pores. Subsequently these pores merge in a single median pore, from which right and left pore-canals diverge. As the larva grows in size, other arms sprout out. The postero-dorsal arms, as in other Echinoidea, receive their skeleton (which is latticed) from a new calcareous aster on each side. The præoral arms, which are in front of the mouth, central to the antero-lateral arms, receive their support from branches of a single median aster situated above the œsophagus. So far eight arms are developed, as in other Echinoid larvæ But in Echinocardium other arms make their appearance Two of these, the antero-dorsal, receive their skeleton as branches of the rods supporting the præoral arms two others, the postero-lateral, are supported by outgrowths from the base of the club skeleton. As these arms grow in length the aboral club undergoes absorption and is reduced at the time of metamorphosis to a short rounded prominence.

As in other Echinoid larvæ an invagination appears on the left side, the floor of which becomes converted into the oral disc of the young Spatangoid On this disc the adult spines grow and in the centre the adult mouth is formed The disc increases in size till it takes in all the left side and part of the right side of the larva, displacing the anus to one side Then the larval arms are rapidly absorbed the stomodæum becomes disconnected with the gut and shallows out, and the oral portion of the larva shrinks to an insignificant knob The young Spatangoid has no spines on the aboral surface (in this it contrasts with the young Echinus) All its spines are pointed except a circle situated at one end, these have broad flattened ends and constitute the only distinctive Spatangoid feature as yet visible The mouth is surrounded by five plates, from each of which springs an inwardly directed spine From the rhythmical movements of these spines I am inclined to think that they represent the teeth of regular Echinoids

---

3 *A Preliminary Account of the Development of the Starfish* Asterias rubens *(L.)*. *By* J F. Gemmill, *M D*

Artificial fertilisation at the Millport Marine Biological Station; complete subsequent development in Embryology Laboratory, Glasgow University; methods employed to secure circulation, &c, in the hatching vessels

General chronology of development until completion of metamorphosis; movements of the larvæ, the cœlomic fluid circulation, a pulsating 'heart-complex'

Mode of development of the chief cœlomic cavities, probable homologies of these cavities on the right and left sides, light thrown on this question by larvæ with double hydrocœle, comparison with *Balanoglossus*

---

4 *On the Hybridisation of Echinoids* *By* H M Fuchs, *B A.*

The work described was done in the laboratory of the Marine Biological Association, Plymouth, in conjunction with Dr. Cresswell Shearer and Mr W. de Morgan, during 1909-12 The present paper deals chiefly with the experiments of this spring and summer. An account of the work of 1909-11 has already been published [1]

In order to arrive at definite conclusions from experiments on the hybridisation of Echinoderms two principles must be followed : (1) The hybrids should be healthy. The maldevelopment of a character in an unhealthy larva can easily vitiate the results (2) The characters of which the inheritance is investigated should be definite in the parental forms—preferably present in the one while absent in the other The variation curves of the pair of characters should not overlap Owing to the elaboration of methods of rearing Echinoids up to and

[1] *Jour M.B A*, vol ix

beyond metamorphosis, it has been possible to observe these conditions in this work. The early and variable larval characters have been discarded in favour of definite ones developed by the late plutei

The forms used for the hybridisation were the three English species of *Echinus* The characters studied in the larvæ were as follows . The late pluteus of *E miliaris* has no posterior epaulettes, but has a pair of green pigment-masses in the anterior epaulettes On the other hand, the plutei of *E. esculentus* and *E acutus* possess a pair of posterior epaulettes, but lack the green pigment. *E. esculentus* and *E. acutus* are similar with regard to these characters and behave similarly in their inheritance.

There has been a difference in the inheritance of these characters in different years In 1909 11 the characters in hybrids between *E. miliaris* and *E esculentus* were invariably inherited through the maternal parent, the reciprocal crosses being thus unlike In 1912 *E esculentus* ♀ × *E miliaris* ♂ has been maternal as previously, but the reciprocal has been paternal The maternal inheritance has thus changed into a dominance of *E esculentus* over *E miliaris*

While in former years there was no exception to the rule given, in 1912 several cultures have shown a difference One fertilisation gave larvæ, some paternal, others maternal, for both characters In several cases the hybrids have all inherited the absence of green pigment from one parent, while some of the larvæ have had both, some one and some neither posterior epaulettes The last-mentioned shows that the characters may be inherited independently of one another, the absence of green pigment coming from *E esculentus* and the absence of epaulettes from *E miliaris*

No parallel seems to be known to this reversal of inheritance The cause is unknown, but it is suggested that it is due to a condition of the parents, and not to the environment of the larvæ because (1) one of the pure forms has been much more difficult to raise this year than in previous years, (2) different cultures from the same fertilisation always showed the same inheritance, (3) it has been impossible to alter the inheritance artificially

In the past summer large numbers of pure-bred and hybrid Echini have been raised through metamorphosis The inheritance of a tube-foot character has been investigated, but it has been found to be too variable to give definite results It is hoped that a second generation of the hybrids will be obtained Some are already large and old enough to be mature

---

5 *On Methods of raising Parthenogenetic Larvæ of* Echinus esculentus *By* Dorothy Jordan Lloyd, *B Sc*

This work was carried out in conjunction with Dr Cresswell Shearer during the seasons 1911 and 1912 at the laboratory of the Marine Biological Association, Plymouth. The experiments were made in order to obtain a method that could be applied to the sea-urchins of the English coast, and in the hope of raising some of the parthenogenetic larvæ to maturity We have been successful in rearing the plutei through the late stages, and large numbers in our cultures formed Echinus-rudiments A few of the larvæ completed their metamorphosis, but we have not succeeded in getting the young urchins to live for more than a few days

The methods used were those elaborated by Loeb and by Delage, and a new method which combines certain features from each of these Loeb's method consists in treating the unfertilised eggs with butyric acid to cause membrane formation, and subsequently with hypertonic sea-water Owing to the condition of the sea-water at Plymouth it is necessary after membrane formation to place the eggs in water of raised OH-ion concentration before treating them with hypertonic sea-water The modification of Loeb's method which we employed is as follows. The unfertilised eggs were placed in —

(1) 3 c c N/10 butyric acid+50 c c sea-water for 1 5 minutes
(2) 0 2 c.c N/10 NaOH + 50 c c sea-water for 6 minutes
(3) 8 c c 2·5 M/NaCl + 5 c c sea-water for ·75—1 hour

The best experiments with this method gave 60 per cent blastulæ The larvæ were healthy and grew well.

Delage's method consists in treating the unfertilised eggs with tannic acid and ammonia in a mixture of sea-water and cane-sugar The proportions we found most favourable for *E. esculentus* at Plymouth were 10 c c sea-water + 40 c c. cane-sugar solution (strength, 388 grms. to a litre) + 1 4 c.c M/60 tannic acid the unfertilised eggs were placed in this for six minutes, and then 1·5 c c. M/10 ammonia were added for one hour. We have obtained 80 per cent blastulæ by this method, but they are not healthy and die off rapidly during the first week There is no membrane formation by Delage's method

The method which we have found most successful consisted in treating the unfertilised eggs first with butyric acid to cause membrane formation as in Loeb's method, and then by Delage's method as described above. In this way we have obtained as many as 90 per cent blastulæ The larvæ are vigorous and grow for the first three weeks as rapidly as larvæ from fertilised eggs

---

6 *A Sessile Ctenophore,* Tjalfiella tristoma *(Mrtsn), and its Bearing on Phylogeny* *By* Dr. Th Mortensen.

On an expedition to West Greenland in 1908, Mr Ad S Jensen found in the deep Umanak fjord a curious animal, attached to the stems of *Umbellula Lindahlii* It proved to be a Ctenophore of quite unusual interest, being the first sessile Ctenophore known, moreover, it was found to be viviparous, a condition likewise hitherto unknown among Ctenophores [1]

The shape of the animal is quite unlike anything else among Ctenophores The body is compressed, elongated in the transverse plane, and has at each end a tower- or chimney-like elevation with an opening at the top This shape is the natural consequence of the fact that the animal attaches itself with its mouth, thus making it impossible for the mouth to perform its duties as such A functional mouth-opening being, however, a necessity, the animal helps itself in this way, that the mouth-edges are turned upwards and raised on the said little towers The animal thus gets in reality three mouth-openings, the original one remaining open though out of function The costæ have totally disappeared The apical organ is rudimentary, being—as a static organ—of no use in a sessile organism The tentacles are simple There are no meridional canals, on the other hand, there is a branching canal-system as in *Cœloplana* and *Ctenoplana* Four pairs of prominent knobs, situated along the upper side of the body, represent the genital organs, the structure and arrangement of which are in perfect accordance with that typical in Ctenophores The eggs are developed in brood-chambers on the sides of the body The young, which is a true Cydippid, with well-developed costæ, has a pair of oral transversal lobes, recalling the lobes of the Lobatæ It swims about for a very short time, then attaches itself with the mouth (more precisely, with the inside of the spread-out oral lobes), looses its costæ, and at once begins to form the chimneys with the secondary mouth-openings

Tjalfiella is doubtless nearest related to *Cœloplana* and, especially, *Ctenoplana* The several important anatomical differences apparently existing between *Tjalfiella* and *Ctenoplana*, the latter being stated to have unisexual genital organs with separate ducts, a peculiar gastric gland, chloragogenous cells, &c , appear to rest altogether on misapprehension

In regard to phylogeny great importance attaches to *Tjalfiella* The theory of Selenka and Lang, according to which the Polyclads derive from the Ctenophores, has been much criticised in recent times, especially by Willey, who maintains that Ctenophores and Polyclads have developed along different lines from forms like *Cœloplana* and *Ctenoplana*, which are thus regarded as the most primitive of all Ctenophores The anatomy and development of *Tjalfiella* are, however, decidedly in favour of the theory of Selenka-Lang, it can no longer be doubted that the Platyctenida are really the most specialised of all Ctenophores, showing the way along which the Polyclads developed from the

[1] A preliminary description was published in *Vidensk Medd. Naturh Foren København*, 1910; the full report has been published in May this year (1912) in the 'Danish Ingolf Expedition,' vol v , 2, 'Ctenophora '

Ctenophores. Consequently the Ctenophores should be classified with the Plathelminths, not with the Coelenterates

For the question about the origin of the bilateral from the radiate type *Tjalfiella* is likewise of considerable value. The first step in this transformation is the *splitting up*, along the transverse axis, of the oral side of the body, as seen in the embryo of *Tjalfiella*, and also in *Ctenoplana* The next step is the wandering of the apical organ towards the anterior end, and the bending of the main axis, as shown by Lang Only the inside of the oral lobes is ciliated, seeing now that in *Cœloplana* only the underside of the body is ciliated, it appears that the whole underside of *Cœloplana* corresponds to the inside of a pair of oral lobes. Also in the pelagic larvæ of Polyclads the same splitting up of the oral side, along the transverse axis, appears to take place, the larval processes being the homologues of the oral lobes of the young *Tjalfiella* and of *Ctenoplana* The ciliated bands are a specialisation of the general ciliation, which here likewise occurs at first only on the inside of the lobes, these bands accordingly represent a pre-oral and a post-oral band, not a pre-oral band alone Herewith further, the origin of the two ciliated bands, as also of the ciliated part between the two bands, in the *Trochophora* appears to be naturally explained

7 *On some New Alcyonarians*
By Professor J ARTHUR THOMSON, *F R S E*

8 *Report on the Occupation of a Table at the Zoological Station at Naples*.—See Reports, p 186

9 *Final Report on the Index Animalium*.—See Reports, p 113

10 *Report on the Biological Problems incidental to the Belmullet Whaling Station*.—See Reports, p 115

11 *Final Report on the Inheritance and Development of Secondary Sexual Characters in Birds*.—See Reports, p 187

12 *Fourth Report on the Feeding Habits of British Birds*.—See Reports, p 189

13 *Twenty-second Report on the Zoology of the Sandwich Islands*.—See Reports, p 189

14. *Report on Zoology Organization*.—See Reports, p. 190

15 *Report on the Occupation of a Table at the Marine Laboratory, Plymouth*.—See Reports, p 190

16 *Fifth Report on Experiments in Inheritance*

17 *Report on the Formulation of a Definite System on which Collectors should record their Captures*

18. *On the Distribution of* Saccammina sphærica (*M. Sars*) *and* Psammosphæra fusca (*Schulze*) *in the North Sea, particularly with reference to the Suggested Identity of the Two Species. By* EDWARD HERON-ALLEN, *F.L.S., F.G.S., F.R.M.S., and* ARTHUR EARLAND, *F.R.M.S.*

These foraminifera, belonging to the family Astrorhizidæ, and originally described as from the North Sea, but occurring also in all the great oceans, have been the subject of considerable controversy. Dr. Ludwig Rhumbler asserts that *Psammosphæra* is only an immature stage of *Saccammina*. Several zoologists have accepted his view, apparently without any verification of the evidence tendered, except in the case of Dr. Lucke, who supports Rhumbler's theory in general, although differing in certain minor conclusions.

Their observations may be divided into two groups—(1) The nucleolar structure of the protoplasm, and (2) the nature of the composite shell wall and its cement. We do not propose to deal with the first group of observations, beyond recording our opinion that, in the present state of knowledge of protoplasm in the Astrorhizidæ, no generic distinctions can be based on such evidence alone. Our observations will be confined to an analysis of their evidence as based on the structure of the composite test.

Rhumbler's description of the life history of *Saccammina* may be divided into seven stages, which again fall into three groups, each of which, in our opinion, represents a distinct and specific organism.

The stages are as follows:—

STAGE I.—A small portion of protoplasm is extruded (from the parent *Saccammina* assumed), and settles on the parent shell, or on an adjacent sand-grain. It secretes a sessile monothalamous test of extremely fine sand grains, and of a white colour.

STAGE II.—Numerous sponge spicules are built into the test, which becomes hispid.

STAGE III.—The spicules are discarded and replaced by larger sand grains. *These three stages form the first group, the 'Primitiv-gehaus' of Rhumbler.*

STAGE IV.—The sessile organism becomes detached. The sand-grains are replaced by larger grains irregularly cemented together. The exterior is very rough, and there is no aperture. *This stage forms the second group, the 'Psammosphæra' stage of Rhumbler.*

STAGE V.—The rearrangement of the larger sand grains with their flat surfaces on the exterior of the test causes it to assume a more regular outline. A chink or fissure appears between several grains, which eventually develops into the general aperture.

STAGE VI.—The fissures between the sand-grains are filled up with a mortar of cement and small grains. The test assumes a regular pyriform outline owing to the development of the aperture.

STAGE VII.—The internal fissures are similarly filled. The test becomes nearly globular, with a large general aperture situated on a nipple-like protuberance. *These three stages form the third group, the 'Saccammina' stages of Rhumbler.*

Now, if Rhumbler's theory is to hold ground it is evident that these three stages should be constantly associated in dredgings. Such is not the case. As a result of the examination of about 150 dredgings, made over an enormous area in the North Sea and the adjacent waters, we have no hesitation in affirming that the life-history of *Saccammina*, as recorded by Rhumbler, is a composite sketch, involving three separate and generally recognised specific organisms:—

Stages I. to III. represent the life-history of *Crithionina mamilla* (A. Goes), a sessile rhizopod which, although often associated with *Saccammina sphærica*, has a wide distribution apart from that species.

Stage IV. is *Psammosphæra fusca* (Schulze), an extremely variable species, which occurs both free and sessile, but is in all its stages normally recognisable by the absence of a general aperture. In our dredgings it often occurs with *Saccammina sphærica*, but more frequently without. It is capable of existence under conditions of depth and surroundings in which *Saccammina* NEVER exists. Where co-existent with *Saccammina* it frequently attains a size equal to or

greater than the average size of *Saccammina*, whereas, according to Rhumbler's theory, it should have passed into its adult stage, and finally it presents two well-marked varieties, var *parva* (Flint) and var *testacea* (Flint), which have no corresponding development in Rhumbler's life-cycle

Stages V. to VII represent the complete life-cycle of *Saccammina sphærica* (Sars), so far as it is a shell-bearing organism The smallest specimens which we find (0 3 to 0·4 mm) do not present any less difference in size, as compared with the adult, than is observable in the majority of rhizopods, and there is no reason for supposing that *Saccammina sphærica*, whatever may be the earliest stages of its life-history, at present unknown, is in its shell-bearing stages in any way different from the adult, except in its smaller size, its somewhat rougher and less finished exterior, and in the fact that its general aperture is in the earliest stages a mere chink or fissure, which gradually develops into the nipple-like protuberance on which the aperture of the adult is placed

We present in support of our contentions a chart showing the relative distribution of *Psammosphæra* and *Saccammina* in the area examined, and a series of drawings showing all the stages in the development of the three organisms involved

---

10 *The Relation of the Mechanics of the Cell to the Mechanics of Development* By Professor Dr LUDWIG RHUMBLER

W Roux has summarised the aim of the study of developmental mechanics in a single phrase, namely, 'the mechanistic explanation of developments' The terms 'mechanics' and 'mechanistic' are to be understood here in the most general philosophical sense of the doctrine of the mechanistic course of events—that is to say, of events as subject to causality The science of developmental mechanics has, therefore, to establish those factors which determine the path taken by the development of the living being in its course from the egg to the end of the embryonic life, quite irrespective of the nature of those factors whether chemical, physical, or of any other nature whatsoever

It is obvious that within a field of research of such wide extent as that covered by developmental mechanics according to this definition, special lines of research will be developed, which, by limiting their scope so as to investigate certain definite modes of activity, while leaving unexplained other manifestations of the organic activity, lighten their self-imposed task and strive to attain exact results Such a side-branch of developmental mechanics is that which deals with the purely physical aspect of the processes of development—that is to say, which puts on one side the chemical composition of the embryonic body, and takes into consideration only the physical factors which come into action in the displacements and rearrangements during the process of organic form-production This special branch of developmental mechanics may be termed *developmental dynamics*, it comprises 'the physics of the processes of modification and determination of form in the embryo'

It has never been disputed from any side that physics and dynamics of this kind are in operation during the course of embryonic development, not even by the neo-vitalist Driesch, for where masses are moved and arranged, the laws of the movements of masses—that is to say, of dynamics—must be operative The application of physical laws to the living substance in process of development must, however, break down at the outset and lead to no result, if the physics of this substance were dependent in a specific manner upon the chemical composition of the masses in active or passive movement—if, that is to say, every chemically different substance also had its own distinct physical laws, for then it would be confronted by the whole chaos of our ignorance with regard to the chemical structure and mode of activity of the living substance Fortunately, however, this is not the case, dynamic similarity or dynamic equivalence of a system does not necessitate in any way chemical similarity or chemical equivalence A locomotive could be constructed with gold or any other rigid substance possessing the required physical properties instead of with iron, without altering the dynamics of the machine thereby, on the contrary, it is evident that the dynamics of the processes in operation are dependent solely upon the aggregate condition, the mass-relations, and the arrangement of the constituent parts of the mechanical system which is carrying on the processes under consideration.

Developmental dynamics are set free, therefore, from the quite hopelessly complicated chemistry of the living substance

The processes of embryonic form-production are, as is well known, for the most part processes of evagination and invagination of epithelial cell-complexes—in other words, foldings of plates of cells His has already made an attempt to refer these processes of folding to the effects of lateral pressures exerted by various rapidly growing neighbouring cell-territories Roux has shown, however, that in the embryonic body the cell-layers which become folded also undergo their process of folding when they are cut out of their environment, consequently the folding is not a passive process due to pressure of the surrounding cell-complexes, but must be localised actually in the cell-layers themselves that are being folded Many other contradictions with dynamic anticipations have arisen from a consideration of the associations of the cells

It would, however, be quite erroneous to conclude from unfulfilled anticipations of this kind that the application of physico dynamic laws to the cell-layers is unsound, it is evident rather that the embryonic cell-layers cannot be interpreted dynamically merely as flexible plates in the manner suggested by His The cell complexes are not simple dynamical systems, but have attained a high degree of complexity The complication arises from the fact that each cell represents by itself a mechanical system complete in itself To make use of a comparison, a plate of cells is not a simple wall built up of pliable material, as His believes, but an association of automobiles linked together one with another, each of which possesses its own driving force Each of the automobiles can indeed react in a purely passive manner to external influences, if it does not puts its own motor in action, it can even heighten the effect of the external dynamical influence if it lets its motor work in harmony with the dynamical influence, it can, however, on the other hand, derange entirely the results of the dynamic influence by letting the motors of the various autos linked together run in different directions and with varying intensity The dynamics of the cell-layers involved in the embryonic processes of folding can therefore only be made intelligible on the basis of an accurate knowledge of cell-dynamics, the discovery of which is the object of the science of 'cell-mechanics' Without an exact knowledge of the dynamics of the cleavage cells it is quite impossible to understand the dynamics of the cell layers and of the process of form-production

Previous investigations of cell-mechanics, which owe their first foundations above all to Berthold and Butschli, have shown that the dynamics of cells can be understood on the basis of purely physical laws, that fundamentally cells are even relatively simple dynamic systems, the results of which within the cell complexes are only to be analysed with difficulty by the co-operation of many such dynamic systems, but are by no means inexplicable The author now shows by some examples how the dynamic properties of cells, already established by the study of cell-mechanics, are able to elucidate physically in a simple manner whole series of phenomena exhibited by the behaviour of embryonic cell-complexes In spite of such elucidations, however, the fact must not be lost sight of that the science of cell-mechanics can never extend the range of its explanations beyond the physics of the developmental processes alone, it is fully conscious that it leaves entirely unexplained the specific physiological-chemical structure of the living contents, which is subject to the physical form-production But since the science of developmental mechanics covers in its range all the factors, including the physical, of embryonic form-production, it is dependent upon the help of cell mechanics in following out its ambitious aims The study of cell-mechanics prepares the way for that of developmental mechanics

20 *The Method by which the Individual Organism becomes adapted to New Environmental Stimuli by Use-acquirement, and on the Origin and Dependence of Use-acquirements on Variation and Selection of Intra-cellular Units* By C. J. Bond, *F.R C S.*

There is a tendency to regard the germinal variations on which racial evolution depends, and the somatic modifications on which one part of individual development depends, as two essentially dissimilar processes.

The object of this paper is to show that both depend on variation and selection acting on different kinds of units.

The conditions—viz., struggle for existence, reproduction of organisms, and the destruction of unfit varieties—which accompany natural selection are also present during the adaptive response by somatic cells.

The making of use-acquirements by somatic cells coincides with functional activity in these cells. Indirect adaptation through germinal variation coincides with cell division. Both depend on variation and selection among individual cells or among cell parts. Only those cells undergo cell division which are undifferentiated—*e.g.*, germ-cells—or which undergo undifferentiation before division.

The adult nerve-cell in the human subject undergoes neither undifferentiation nor cell division, but has a great capacity for intra-cellular molecular re-arrangement and reconstruction when exposed to altered stimuli.

Indirect adaptation depends on the inter-cellular variations which accompany cell division. Direct adaptation depends on the intra-cellular variations which accompany functional activity in somatic cells.

Examples of Use-acquirements.

Muscular Hypertrophy.—Differs from the neuro-psychic response in mode of origin. It is the result of cell division in muscle-cells and not of variation and selection of the component parts of individual muscle-cells. It is a use-acquirement on the part of the individual, but not on the part of the individual muscle-cell.

The Neuro-Psychic Response.—Is a true use-acquirement. It is not accompanied by destruction or regeneration of individual nerve-cells, but is associated with a process of reconstruction and rearrangement of molecular composition in nerve-cells. The effect of an altered stimulus is to initiate variation in the molecular architecture of the nerve-cell, and to favour the selection and the perpetuation of one out of several modes of intra-cellular metabolism in the nerve-cell. The consideration of neuro-psychical adaptation as a whole also favours this explanation of the origin of use-acquirements. The acquirement by use and experience of new modes of neuro-psychic response depends on the selection of one out of several possible modes of neural activity.

The Acquired Immunity Reaction.—This is a use-acquirement as made by the individual, but it is also the result of variation and selection of body cells exposed to disease organisms. It depends partly on inter-cellular, partly on intra-cellular variation and selection.

Use-acquirements made by somatic cells are not normally transmitted to offspring, that is to germ cells and their descendants, but they are transmitted to the cell descendants of the somatic cells which make them.

The origin of all use-acquirement in a process of innate variation among cell parts explains this apparent anomaly.

---

21. *Speech in Animals.* By Professor R. J. Anderson, *M.D., M.A.*

There is an obvious relationship between the expression of wishes, emotions, &c., by means of words and the capacity to understand words. There are many who seem to believe that a dog, cat, or horse can be trained to understand the common meaning of many words. There are, on the other hand, many who believe that even the monkey, elephant, or parrot have a very limited capacity in this regard, and that the tone of voice, pose or gesture count for much with many animals. Association and the reflex accompaniments seem to count for much. A little dog will learn very soon to associate the presence of some friend with the licking of his lips. Salivation, which is commonly associated with the smell, sight, or thought of food in man, becomes in a dog associated with a nerve stimulus or sound, as the experiments of Pawlov and his pupils prove. The bell that calls the workman from labour to refreshment may lead a dog to 'whine' or bark because of its association. A dog distinguishes between a lively tone and menacing tone; this may be the result of education. And the sense of smell is evidently the most powerful associated sense. We must agree that sight and hearing are not so keen as scent in dogs. The power and disposition to seize upon some salient feature by the eye or ear is easily recognisable. This 'quick-

ness' is apt to lead to fatal errors, but answers the main purpose The sounds that animals emit are apparently, except in man, limited to a few often guttural or modified guttural expressions The bark of a dog is susceptible of slight modifications of tone It varies in loudness and in quality The main cause of the sound is alarm, or a desire to alarm or attract the attention of another dog or the master. It is evidently the most useful sound a dog possesses A dog was probably first domesticated because of its bark The whine is a sound of appeal Thus Franke's dog whined in order to get a box lifted, there was a bone beneath the box Entreating sounds, cries for help, also threatening and warning cries are common amongst many animal tribes C Killogg seems to have learned a good deal about animal language It is clear we ought to guard against assuming that our own interpretations are correct Pain, fear, and anger may cause a dog to howl Some animals do not express a sense of pain unless it be intense Certain sounds make a dog howl This may arise primarily from discomfort, but may afterwards arise from association, just as a dog has been known to sneeze at the sight of a snuffbox Skilled musicians are often visibly affected by discordant sounds A cat whimpers or mews mildly when she wants a door opened Her mew has a different tone when she is angry or hungry Little guinea-fowl and pheasants soon learn to run over to a 'sod' to wait in expectation of a visitor turning the earth up to expose the worms The growl is a composite tone of defiance in a dog Its value is most readily interpreted by a dog Franke gives an interesting example of a snorer setting some dogs growling They did not find out their mistake for some time The bark, the tone of alarm, is akin to the noise made by monkeys It may, perhaps, develop into a battle cry, as a number of barking dogs would tend to intimidate adversaries, as happens in the case of men As growling and barking are infectious, so the sight of pugnacious individuals always excited a collie of mine He acted as peacemaker when he encountered cattle or fowls quarrelling, but joined in the fray where dogs were the combatants The early training of dogs, horses and other animals goes far to obliterate any tendency to marked development of original lines of thought It is to be doubted whether any great advance could be made in the development of a dog language, even though 'dog' means bark and 'hound' comes from howl But that a series of combinations might be possibly made out of the sounds which adult dogs have at their disposal cannot be doubted The study of young dogs would be more fruitful in view of the fact that the vocal apparatus might be modified

---

22 *Notes on the Skull of a Grampus, &c*
By Professor R J Anderson, *M D*, *M A*

A grampus (griseus) was stranded some time ago near Galway The skull of this specimen is more complete than that of the previous one The length is 47 5 cm Greatest breadth, 31 5 cm The inter-nasal suture, 4 cm to left side of the median line, right nasal bone is 4 6 cm across, the left 4 cm Antero-posteriorly right is 5 5 cm across, the left 4 5 cm Both measurements were slightly oblique Premaxillæ, which reach to the tip of the rostrum, show the right longer (40 cm) than left (36 cm) and broader (6 5 cm) than left (5 cm) The right reaches higher than left, so that the left frontal is not so much covered Two large foramina in each maxilla; one in each premaxilla The former run inwards and backwards The frontal is exposed for 3 5 cm near the middle line on the upper surface The palatines are 3 cm broad at the inner part of the palate They run back and make a V with the point reaching between the pterygoids and enclosing the pointed maxillæ in front and internal to them. The palatines are much wider at the outside where they turn round to sides. They are 8 cm from front to back at the sides Vomer is 5 cm. behind No teeth in the upper jaw

Mandible, 38 cm long, 11 cm vertical behind

Sockets for five teeth on right side, four on left

Condyle is 4 cm above the angle and 3 cm below the level of coronoid

The condyles of the occipital bone are much further apart than in globiocephalus The least distance is $\frac{3}{8}$ inch. The distance between the condyles in

Beluga is greater There may be an approximation in the older individuals, as happens in some other groups

A large cetacean was shot in the Bay some weeks ago.[1] It evidently belonged to the porpoise kind or was a close ally to this genus It measured 12 feet, and had pointed broadish fins, black above, white below, and was a male Head 20 inches long, 10½ inches broad, 9½ inches high. The teeth were wanting at the middle of the upper and lower jaws of the left side There are, however, seventy-three in all remaining. The original number seems to have been a hundred (all sides). The back lower teeth of left side have been unevenly worn owing to the unequal pressure of the teeth above, several teeth are loose The œsophagus is about 6 inches across, and glandular The stomach had a capacity of 20 litres The first stomach is very large, the second rounder and smaller. It may be said that the teeth are much ground down There is a duodenal ampulla at some distance from the stomach The intestine was 160 feet long, indicating that the absorption was somewhat slow The stomach contained the remains of several fish, and some fragments of crustaceans carried by the victims possibly The dentition of some of the Galway cetaceans is as follows —

	No of Teeth in Upper Jaw		No of Teeth in Lower Jaw	
	Right	Left	Right	Left
Dolphin	41	44	44	43
Grampus griseus	0	0	5	4
Globiocephalus Melas (Pilot)	10	10	7	8
Beluga (White fish)	9	9	6	7
Orca (half of upper jaw)	—[2]	9	—	—
Mesoplodon (Cuvier's)	0	0	1	1
Tursiops	24	24	24	24

MONDAY, SEPTEMBER 9

Joint Discussion with Section I on the Physiology of Aquatic Organisms.—See p 651

The following Papers were then read —

1 *Some Features in Bird-migration as observed during Eight Weeks' Residence at the Tuskar Light-station, Co Wexford.* *By* C J Patten, *M A , M D , Sc D*

In such a comprehensive study as the migration of birds as carried out personally, over a considerable period of time, at an isolated rock on which a lighthouse has been built, with a lantern of powerful illumination, so many problems present themselves for investigation, and so extensive and intricate are the statistics, that in order to cover the ground at my disposal I must here confine my remarks to some special features in connection with my subject which I hope will be of general interest To the ornithologist of a country, and especially in the case of a small one like Ireland, where a complete knowledge of the avifauna is not so difficult to acquire, one of the most fascinating objects is to wait and watch for species which, either unknown or of very rare occurrence in their natural habitat, are attracted and decoyed by the luminous beams of the lantern under certain meteorological phases, when on passage. It is chiefly from the lighthouse that so many birds new to Ireland have been recorded, and during my visit I was enabled to add a few more to the list Another feature of

[1] One specimen labelled *Delphinus tursio* (Fabr) in the Copenhagen Museum is like this in skull and backbone Two others labelled *Delphinus tursio* (Fabr) and *Delphinus tursio* (Cuv) have sharp teeth and are smaller

[2] Absent

considerable interest in dealing with bird-migration presents itself at the Tuskar light-station, namely to what extent certain supposed desultory or mere local migrants journey? Several knotty points can, I am of opinion, be disentangled as we study this subject at such an excellent observatory as the Tuskar Rock. For any land birds which appear, even when they alight and rest a few hours, are bent on making a passage No land birds could reside here, where fresh water to drink is unavailable, food is very scarce (for some species absent altogether), and the rock is frequently wave-swept The third and last feature I wish to refer to is in connection with the study of variation. Splendid opportunities present themselves, because such large numbers of certain species fall victims by striking the lantern that these can be collected and preserved with facility.

---

2 *Note on the Method of 'Bird-marking' as applied by the Aberdeen University Bird-migration Inquiry* By A LANDSBOROUGH THOMSON, *M A.*

The method of 'bird-marking' consists essentially in marking large numbers of birds which have been caught without injury or found as nestlings, in the hope that a small percentage of them will by their reappearance afford data of value to students of migration (The marks employed are usually light metal foot-rings broad enough to bear an inscription) The method is to be considered as supplementary to others, and as it attacks the problems from a new aspect, that of the individual bird in contradistinction to that of the general movement, it may confidently be expected to yield new facts of importance

The method has been successfully used on the Continent, notably in Denmark and in Germany, for several years, but had not been known in the British Isles previous to 1909 except on a small and very restricted scale In that year two large inquiries were set on foot, having a wide scope, and using the more thorough and scientific method of separate identification numbers on each ring in place of mere date marks A few results of the Aberdeen University Inquiry may be cited as illustrating the possibilities of the method, though it must be admitted that it would be premature to draw conclusions from them for any other purpose —

Record of an English-bred swallow (*Chelidon rustica* (L)) returning to breeding place the following summer Record of a Scottish bred swallow returning to birthplace the following summer

Record of a Scottish-bred song-thrush (British race = *Turdus philomelus clarkei* (Hart)) migrating to Portugal in its first autumn

Record of a meadow-pipit (*Anthus pratensis* (L)) migrating from England to Portugal in autumn

Records of starlings (*Sturnus vulgaris* (L)) summering in Arctic Norway migrating to or through Scotland

Records of Scottish-bred lapwings (*Vanellus vulgaris* (L)) migrating in winter to Ireland and Portugal

---

3 *Note on an Inquiry as to the Food of Birds, conducted by* MISS LAURA FLORENCE, *M A , B Sc*

This inquiry was begun in October 1909, under the supervision of Professor Thomson, and with the valuable co-operation of Professor Trail The investigator, Miss Laura Florence, M A , B Sc , has examined about 1,800 birds, chiefly from agricultural land in the N E of Scotland. It is too early to draw many definite conclusions, but the inquiry shows the need for examining large numbers from different areas, and throughout the year, if trustworthy information is to be forthcoming as to the injurious or beneficial activities of common birds Many current opinions on this subject rest on far too narrow a basis

Birds of 95 species have been examined, but large numbers of any one species have not been procurable except in a few cases, such as rooks and gulls In some cases the verdict given by previous investigators, such as Professor Newstead,

has been confirmed, *e g*, as to the injuriousness of house-sparrow, wood-pigeon, and carrion-crow, and as to the beneficial activity of hedge-sparrow, fieldfare, lapwing, and plovers. On the other hand, there are several cases in which the results up to the present do not altogether confirm previous opinions, thus the diet of the black-headed gull and the common gull shows a striking resemblance to that of the useful lapwing It is much to be desired that this inquiry, and others like it elsewhere, should be continued for a term of years, and the co operation of farmers and others interested is solicited

---

4 Chordeuma obesum, *a New Parasitic Copepod Endoparasite in* Asteronyx loveni *By* Professor HECTOR F E JUNGERSEN

This form is a common parasite in the interior of *Asteronyx loveni* (whicl itself is fixed to living Pennatulids and Gorgonians, in the Skagerrak always t *Funiculina quadrangularis*) With few exceptions I found it present in ever specimen of *Asteronyx* examined The parasite is enclosed in a thin membranou capsule formed by the host, and these galls may be found practically in ever part of the interior except inside the gonads and digestive cavity Sometime they are so numerous that the whole interior of the host seems made up by th parasites, in such cases the gonads of the *Asteronyx* seem not to develop Eacl gall contains either a male or a female Copepod If the latter is ripe the gal encloses also its eggs and brood, and very often a male (seldom two), and empt spermatophores The eggs do not form ovisacs, but are loosely cemente together in one large mass, distending the one end of the gall, filling every spac left at the posterior part of the mother The male, if present, is completel imbedded in the egg-mass Both embryonic development and most of the post embryonic metamorphosis occur inside the gall As larvæ of Cyclops shap the young leave the gall, subsequently either settling in the same host, thu augmenting the stock of parasites already present, or they leave by way of th bursal openings to infest other individuals of *Asteronyx*, making their way int these through the same portholes In both cases the larva itself by it hooked maxillæ to some point of the tissues lining the bursæ, and causing then to produce the gall The larval cuticle is now cast off, and the parasitic forn ensues No more moultings take place, but the Copepod and its gall continu for a while to grow considerably, the parasite at the same time undergoin slighter modifications in the shape of the body and its appendages, and develop ing its inner structures; finally the full size and sexual maturity are attained

The *adult female* is 4 5 3 mm in length, sausage shaped, composed of cephalon, four thoracic segments, and an unsegmented post abdomen The cepha lon carries in front short, unsegmented *antennules*, with two blunt termina processes and a small ventro lateral spine Immediately in front of the moutl is a pair of slender papilliform appendages, the *antennæ* (an antennal glan being present) Close behind the mouth are the *maxillæ*, the largest and th only segmented appendages found, consisting of three segments, the terminal on forming a hook *Eyes, mandibles*, and *maxillulæ are wanting*

Each of the thoracic segments carries a pair of short, conical, parapodia-lik feet; in young specimens the terminal part—like that of the antennæ—is hairy Each foot represents the *outer* branch of the biramous larval swimming foot In young, immature specimens a rudiment of the inner branch may be preserve on the second, third, or fourth pair Between the second and third thorac segments is a deep constriction here the membranous wall of the gall fits tightl in, thus forming two compartments, the posterior containing the hind part o the female, the egg-mass and eventually the male The anterior part of the post abdomen is as broad as the thorax, carrying on the ventral surface the genita openings; on each side it sends out a large rounded process The remainin part of the post-abdomen forms a short, narrow appendix, sending out a blun conical process, dorsally at the base and terminating in two short bifurcat spines The whole post-abdomen represents three segments There is *no anus* and no trace of an intestine inside the post-abdomen The digestive apparatu consists of a capacious stomach, ending blindly in the last thoracic segment, an

in front connected through a narrow œsophagus and pharynx with the mouth In the stomach is always found a large, concentrically laminated ovoid body, probably of excretory nature There are two rounded ovaries in the cephalon, each sending out a transverse narrow process reaching its fellow in the middle line; an oviduct passes laterally from each ovary to the genital opening, narrowing in the third thoracic segment and again widening, where it opens into the short vaginal duct. Close to the genital opening debouches a short duct from an unpaired receptaculum seminis, surrounded by a mass of unicellular glands

The *adult male* is much smaller, at most ca 2 mm in length It seems quite unlike the female, slender, sub cylindrical, curved, and resembling an insect-maggot, but closer inspection reveals fundamentally the same structure, the same appendages, &c, as in the female, the antennules somewhat less clumsy, the maxillæ larger and stronger, the thoracic feet almost thread-like, in young individuals, with a proportionally large inner branch, rudiments of which are generally preserved in the adult on the second and fourth pair. The body tapers into the post-abdomen, the genital part of which bears lateral outgrowths corresponding to those of the female but firmly chitinised and backwardly directed The alimentary canal is like that of the female, the testes and their ducts corresponding in form and position The distended terminal part of the sperm-duct contains the spermatophore, with a long thread-like neck reaching through the whole duct close to the testis

The *Nauplius* has the typical three pairs of appendages and two simple caudal setæ; *eyes are wanting* as in all later stages. At the first moult a pair of *maxillulæ* are added, as small cylindrical warts, each with a long terminal seta This *first Metanauplius* changes into a *second*, provided in addition with a pair of large *maxillæ* and two pairs of bifurcated *swimming-feet*, and rudiments of a third and fourth pair The *fourth stage* is very interesting: the maxillulæ are completely lost, the outer branch of the *antennæ* forms an empty cuticular case without any setæ, both branches and almost the whole stem of the *mandible* are likewise empty, naked sheaths, only at the very base enclosing a minute papilla of tissue; the maxillæ are increased in size and directed forwards, the first and second pair of feet more fully developed, the third and fourth below, but still small, the four thoracic segments are distinct, and a post-abdomen indicated The fifth stage is a '*Cyclops-stage*,' with a short, triply-segmented post-abdomen, four pairs of swimming-feet with short setæ on both branches, the mandibles are completely lost, the antennæ short, slender, and unbranched This stage changes into the *Cyclops-larva* (sixth stage) found outside the maternal gall This is elongated, laterally compressed, the slender three-segmented post-abdomen is short; it contains no trace of an intestine or anus, the terminal segment is provided with two pairs of plumose setæ (all the previous stages have only the two nauplial caudal setæ), but without furcal appendages The antennules, hitherto of the simple three-segmented type of the nauplius, are now composed of seven segments, carrying several setæ, especially along the anterior border, and three large aesthetascs. The small, short antennæ show three slender joints, the last with two terminal setæ, the maxillæ are three segmented with curved terminal claw The four pairs of thoracic feet consist each of an unsegmented stem and a larger outer and a smaller inner plate shaped ramus, the first with five, the latter with three stiff, non-plumose setæ. This larva—as already stated—moults and changes into the parasitic form (seventh stage), which by-and-by attains the size and shape of the adult.

The systematic position of the new genus I am unable to indicate at present It seems not to be related to any parasitic copepod known to infest other echinoderms. The ectoparasitic *Asterocheridæ* seem to differ widely; and the endoparasitic *Pionodesmotes phormosomæ* (Bonnier), shortly mentioned and figured by *Richard* (1910) as living in galls inside the shell of *Phormosoma uranus* (W Th) as well as '*Philichthys amphiuræ*'—hitherto the only endoparasitic copepod found in any ophiuroid—provisionally described by *Hérouard* (1906), are both so incompletely known that no real judgment can be made concerning their structure or possible relation to our new genus (or any other parasitic copepod)

5. *Reissner's Fibre and the Sub-commissural Organ in the Vertebrate Brain* By Professor ARTHUR DENDY, *F R S*

The sub-commissural organ is a groove, or pair of grooves, lined by much elongated, ciliated, epithelial cells, and situated beneath the posterior commissure From these cells originate a large number of very slender fibrillæ—probably elongated cilia—which unite together to form Reissner's fibre, which extends as a highly elastic, tightly stretched thread backwards through the brain cavities and the *canalis centralis* of the spinal cord to the extreme end of the latter, where it is attached to a plug of connective tissue lying in the *sinus terminalis* and blocking up the terminal neural foramen Both Reissner's fibre and the sub-commissural organ are well developed in all the great vertebrate groups from cyclostomes to primates.

Reissner's fibre was interpreted by Porter E Sargent as a bundle of nerve-fibres which form a short circuit for motor optic reflexes, enabling animals to turn more rapidly away from a sudden source of danger The sub-commissural organ (ependymal groove) was regarded as a mere attachment plate for the constituent nerve-fibres This view, though somewhat widely accepted, was based upon altogether insufficient evidence and cannot be maintained The recent researches of Nicholls in particular have shown that Reissner's fibre is not of a nervous nature Dendy recently suggested that the sub-commissural organ might be a kind of intra cerebral sense-organ, concerned, together with Reissner's fibre, in automatically regulating the flexure of the long axis of the body Variations in the flexure of the body might cause variations in the tension of Reissner's fibre, and these might act as stimuli upon the cells of the sub-commissural organ Such stimuli might be transmitted to ganglion cells, by which in turn the flexure of the long axis of the body might be controlled This view was supported by the fact, demonstrated by Dendy and Nicholls, that in man, with his erect posture and but slightly flexible vertebral column, the sub-commissural organ is reduced to a mere vestige—the mesocœlic recess—while Reissner's fibre is probably absent

Nicholls has recently experimented with regard to the function of Reissner's fibre and the sub-commissural organ in fishes, and finds his results in harmony with Dendy's suggestion He finds that in some fishes the *filum terminale* of the spinal cord projects beyond the vertebral column into the tail fin, and that a very slight puncture with the point of a scalpel in this region is sufficient to sever Reissner's fibre After the operation the fish assumes a characteristic attitude, with the tail bent upwards, which it retains for some days He concludes, from the examination of serial sections, that in these cases Reissner's fibre has sprung forward in the spinal cord for a longer or shorter distance, and coiled itself, as is its wont, into a knot, this knot catches in the *canalis centralis* and prevents further recoil, and the fibre then probably regenerates and forms a new attachment The histological character of Reissner's fibre, its highly elastic nature, and the character of its anterior and posterior connections lend no support to the view that it is a nervous structure

---

6 *On the Cestode Parasites of Trout, with special reference to the Plerocercoid Disease of Trout from Loch Morar* By J W CHALONER

During the past six months I have been investigating the parasites of fresh-water fish, and especially the cestode parasites of the Salmonidæ The trout (*Salmo fario*) from Loch Morar, Inverness-shire, are infected by a larval Bothriocephalid (plerocercoid larva), which appears to cause considerable damage to the fish. Through the kindness of W H Caldwell, Esq , of Morar Lodge, I have been supplied with an abundance of material for investigating the life-history of this particular form, which is quite unknown

These plerocercoids are found encysted in the wall of the intestine and of adjacent organs, the cysts being formed by the tissues of the trout, not by the worm The majority of the cysts were found in the region of the pyloric cæca,

usually in very considerable numbers Sometimes three or four larvæ were found in one cyst, and in some cases the larvæ had emerged and become free in the body-cavity of the trout The larvæ varied in length from a quarter of an inch to eight inches They were about a quarter of an inch broad in the largest forms, and very thick dorso-ventrally While alive they have the appearance of being segmented, and might easily be mistaken for adult tapeworms Sections showed that the sexual organs had not yet begun to develop

The infection is apparently very general in this particular loch, a considerable number of the trout fished being parasitised to a greater or lesser extent, and in some cases the fish become considerably emaciated as a consequence, and their dead bodies have been observed in the river which issues from the loch Endeavours have been made to ascertain whether a similar disease exists in any other part of the country, but so far the information supplied tends to lead me to a negative conclusion for those places from which the information has come, with the one doubtful exception of the lochs of Ross-shire and Sutherlandshire There can be little doubt, however, that the parasite will eventually be found in other localities

We now come to the question of the life-history What is the source of infection, which has, I understand, increased much of late years? From the nature of the parasite it was clear that the sexual form (tapeworm) must be searched for in some vertebrate frequenting the loch, and suspicion naturally pointed to a bird as being the most probable host, for there are no mammals, with the exception of the rat, which could serve the purpose of harbouring the adult worm Of the water-birds frequenting the loch, I have examined three gulls, two of the species *Larus canus* and one *L fuscus*, and also a number of adult and young merganser (*M. serrator*) The only cestode parasites found in the former birds were a number of undetermined *Cyclophyllideæ*, which bore no relation to the larva from the trout One of the adult merganser examined had in its intestine an adult sexual tapeworm in large numbers, and a consideration of the anatomy of this form led to the view that this was possibly the adult I was seeking The parasite was an undetermined species of *Diphyllobothrium* Unfortunately the sex of the particular bird harbouring the parasite was not noted, but all the other adult geese examined were females, and it is possible that these had lost their parasites during incubation, and would regain them later It will be one of the objects of future research to test the validity of this view, which I owe to Mr Caldwell I may mention that this year's young are without any cestode except the *Schistocephalus* now to be referred to

In addition to the isolated instance of the occurrence of *Diphyllobothrium*, sp, all the merganser were found to be infected with the larval and adult sexual form of *Schistocephalus gasterostei* (Fabr), obtained from the stickleback, which forms a large part of the food of these birds This worm lives in the asexual form in the body-cavity of the fish, and, as is well known, attains maturity in the intestine of the bird, which it leaves *per anum* in the course of a few days after infection The mature worm has been observed living free in the water

That the *Diphyllobothrium* found in the intestine of the merganser is the sexual stage of the larva of the trout is by no means proved, but the evidence—*i e*, the anatomical features, based principally upon the size and shape of the head, and the appearance and distribution of the suckers, the presence of the worm in great quantities in one bird, and the difficulty of suggesting any other possible host—is very strong The problem can only be definitely elucidated by means of infection experiments, which are now being performed, but the results are not yet known

It has been suggested that the trout itself may harbour the adult, that the larger trout eat the smaller, and so take the larvæ into the digestive tract, where they attain maturity It is true that an adult tapeworm, *Abothrium crassum* (Bloch) = *Bothriocephalus infundibuliformis* (Rud), the life-history of which is unknown, is present in the alimentary canal of *Salmo fario*, sometimes in considerable numbers, but to judge from the size and shape of the scolex, and the distribution of the suckers, I do not think it is the sexual form of the plerocercoid I have described I have also obtained *Abothrium crassum* from trout from localities where the plerocercoid is unknown

Against the view that the merganser is the final host, the following facts may be alleged —

1 The larvæ in the trout are often considerably larger than the sexual worm in the merganser As, however, little is known of the development of these forms, this objection may eventually prove to be of little importance

2 The number of mergansers hardly appears to be sufficient to infect the whole loch

The only reference that I can find in the literature to a similar parasite is one by Linton in the 'Bulletin of the United States Fish Commission,'[1] entitled 'A contribution to the life-history of *Dibothrium cordiceps*, a parasite infecting the trout of Yellowstone Lake' The author here asserts that the adult worm was found in the intestine of the white pelican (*Pelicanus erythrorhyncus*), but it is doubtful, from the account given, if this identification is correct Infection experiments were not performed, and the figures given tend to indicate that the scolices of the plerocercoid and the sexual worm are somewhat different

Although I have as yet been unsuccessful in working out the life-history of this trout parasite, I have thought it worth while to lay these remarks before the Section, in the hope that they may elicit some information from Scottish naturalists and sportsmen which will lead to the solution of the problem, a result which is very desirable, as in Loch Morar, at any rate, the fishing has become greatly depreciated in late years owing to the prevalence of the parasite

7 *Recent Progress in Helminthology* *By* W Nicoll, *D Sc* , *M D*

The study of the parasitic worms is of considerable importance from two chief points of view, (1) because they are, as a class, the most complete and typical examples of the phenomenon of parasitism, (2) because of the part they play in diseases of man and animals Considered also from the purely zoological standpoint they present many features of interest

During recent years the subject has made rapid advance, this being due to a variety of reasons, the chief of which are the fuller recognition of the part which these worms play in disease, the more thorough application of the experimental method of investigation, and a more satisfactory method of classification In the absence of thoroughly reliable means of identification experimental and other investigations are apt to be involved in confusion For that reason, if for no other, the science as a whole is particularly indebted to workers, such as Looss, Fuhrmann, and Railliet, who have made successful efforts to evolve a natural system of classification The most radical change introduced has been the substitution of internal morphology in place of external characters as the basis of diagnosis, except in the case of the Nematodes, in which chief stress is laid on the head and tail characters, although here also attempts are being made to utilise the internal structure A study of the bionomics of these parasites affords an important criterion of the value of these methods of classification Under earlier systems there appeared to be little correlation between habit and systematic position, a relation, however, which is clearly brought out by the present method Habit, indeed, may in very numerous instances be regarded as a useful indication of systematic position In the matter of development several contributions of revolutionary importance have been made, the most outstanding of which concern the life-histories of the hook-worm (*Ankylostoma*), the blood-fluke (*Schistosomum*), and the Guinea-worm (*Dracunculus*) In the case of the first two, it has been demonstrated that infection may and does take place through the unbroken skin It is over fifteen years since Looss first published this discovery in the case of the hook-worm, but it aroused so much controversy that only within the last year can the matter be regarded as irrefutably proven The fact that the Guinea-worm passes its larval life in a fresh-water crustacean and that infection takes place through the mouth was another discovery which rather upset preconceived notions In the matter of morphology chief attention has been directed to the structure of the so-called shell-gland Recent researches have shown that the shell substance is secreted

[1] Vol. ix., 1899, pp. 337-358.

by the yolk-glands What the function of the 'shell-gland' is remains unknown The old question of the homology of Laurer's canal in the Trematodes and Cestodes has been raised anew, and Odhner has revived the earlier view that the Cestode vagina is the homologue of the Trematode Laurer's canal Perhaps the most interesting new discovery is the existence of a communication between the intestine and the excretory vesicle in certain species of digenetic Trematodes From the medical and veterinary point of view most attention has been paid to Ankylostomiasis, Schistosomiasis (*Bilharzia* disease), hydatid disease, and the relation of intestinal worms to intestinal diseases in general In regard to these many new discoveries of far-reaching importance have been made

TUESDAY, SEPTEMBER 10

The following Paper was read —

Zoological Results of the Scottish National Antarctic Expedition By Dr W S Bruce, *F R S E*

Joint Discussion with Section K on the Origin of Life Introductory Remarks, by E A Minchin, *M A , F R S*

The problem of the origin of life involves two inquiries, both at present of a speculative order the first, as to the nature and characteristics of the earliest living beings, the second, as to the manner in which the primordial form of life took origin and maintained its existence upon the earth

I The *cell*, which may be defined as an individualised mass of *protoplasm* containing at least one *nucleus*, has generally been regarded as the simplest type of organism, the vital unit in the composition of living beings, whether plants or animals It is, however, improbable that the earliest forms of life came into existence as organisms composed of two distinct and separate structural elements, the *nucleus* and the body-protoplasm or *cytoplasm* Which, then, is to be regarded as representing or containing the most primitive elements of the living substance, the cytoplasm or the nucleus?

By most biologists the cytoplasm has been considered to represent the true living substance The earliest living beings have been supposed to be formless masses of protoplasm without nuclei, so-called Monera There are, however, many reasons for believing that the chromatin-substance, invariably present in the nucleus, or occurring as grains, chromidia, scattered in the cytoplasm, represents the primary and essential living matter In support of this view may be urged :—

(1) The fact that chromatin is always present in the bodies of living organisms of all kinds

(2) The experimental proof that cells cannot continue to live if deprived of their nuclei

(3) The fact that in reproduction by fission the chromatin divides first, and is distributed among the daughter-individuals, karyokinesis may be regarded as a mechanism gradually evolved and perfected to ensure an exact quantitative and qualitative partition of the chromatin between the daughter-nuclei

(4) The relation of the chromatin-substance to syngamy and probably to heredity.

(5) The part played by the nucleus in the production of ferments in the cell

(6) The fact that in the minutest living organisms the body appears to consist mainly or entirely of chromatin, cytoplasmic elements being either reduced to a minimum or absent altogether

For these reasons I regard the chromatin as the primitive living substance, and hold the view that the earliest forms of life were very minute particles of chromatin, round which in the course of evolution achromatinic substances were

formed. Within the cytoplasmic envelopes thus produced the chromatin-grains increased in number Organisms of the degree of structural complexity of a true cell arose finally by concentration of the chromatin-grains (chromidiæ) into a compact organised mass, the *nucleus* proper

II As regards the origin of the earliest living beings, it is only possible to frame vague speculations, in the present state of our knowledge concerning the chemistry of the protein-compounds on the one hand, and the metabolism and modes of life of the simplest living things on the other. Whether life originated on the earth itself, as biologists have generally supposed, or was brought in some way to the earth from infinite space, as some physicists have suggested, its first origin involves a synthesis of protein-substances in Nature by some process as yet totally unknown When the earliest form of living being had come into existence, it is very difficult to understand how it could have maintained its life and what it could have fed upon, especially if it were originally wafted from space on to a sterile and barren earth. For light on these problems we must look to the future advance of knowledge, and especially of chemical science

---

The following Papers were then read —

1 *The Development of the Thymus, Epithelial Bodies, and Thyroid in the Vulpine Phalanger* (Trichosurus vulpecula) *By* Miss E A Fraser, *B Sc*, *and* Professor J P Hill

Though the development of these structures has been studied in most orders of Mammals, nothing hitherto has been known of their origin in the Marsupialia The writers have had at their disposal for investigation a relatively abundant material of the diprotodont marsupial *Trichosurus*, and are now in a position to offer a brief summary of their results

In the adult phalanger, the thyroid is situated just caudally to the larynx, and consists of two lateral lobes connected by a median bridge The thymus is remarkable in that it is represented typically by three pairs of glands, viz , a large superficial cervical thymus on each side, situated just internally to the platysma, and immediately caudal to the submaxillary gland, and two smaller thoracic glands, the one cranial to the other, and situated cranially to the pericardium in relation to the corresponding common carotid These thoracic glands, as study of their development shows, represent respectively thymus III and thymus IV They may remain distinct, or they may fuse on one or both sides

The epithelial bodies (parathyroids) vary in number, but there are usually two on each side, one (epithelial body III) near the fork of the common carotid, and the other (epithelial body IV) usually not far removed from thymus IV In addition accessory epithelial bodies usually occur in connection with the cervical thymus

As concerns the development of the thymus, our observations show that the epithelial basis of the cervical gland is derived mainly at least from the ectoderm of the cervical sinus The second gill cleft in early stages is well developed, and possesses an extensive area of fusion with the second ectodermal groove As development proceeds, however, the cleft rapidly narrows, whilst the ectodermal groove deepens inwards to form the so called *ductus branchialis* Both become solid, and we thus have formed an elongated slender cord which ends below in a bulbous enlargement formed from the coalesced walls of the cervical sinus This enlargement, which extends from the ventral end of the *ductus branchialis* to below the junction of the third cleft with the sinus ectoderm, represents the main primordium of the cervical thymus, which is therefore in greater part at least of ectodermal origin, but the participation of the ventral end of the second cleft in its formation cannot wholly be excluded since it is impossible to determine with certainty the limits between the entoderm of the cleft and the ectoderm of the *ductus branchialis*

The third gill-cleft loses its connection with the pharynx relatively early, whilst its connection with the ectoderm of the sinus becomes reduced to a thin cord which eventually disappears The dorsal part of the remainder of the cleft retains its lumen, the ventral part on the contrary becomes solid The cranial

wall of the luminated portion of the cleft gives origin to epithelial body III., whilst the whole of the caudal wall of the same, as well as the solid ventral portion of the cleft (which rapidly grows downwards beyond the connection with the ectoderm of the cervical sinus) furnishes the epithelial basis of thymus III.

The fourth gill-cleft undergoes a corresponding development to cleft III, only here the epithelial body (IV) is derived from the dorsal part of the cleft, including the upper parts of both its cranial and caudal walls, whilst thymus IV. takes origin exclusively from its more ventral portion.

The possession of a fully developed thymus derived from the fourth cleft is a primitive feature characteristic (so far as at present known) of the Marsupials alone amongst the Mammals. Rudiments of a thymus IV have, however, been observed in a number of Eutheria, whilst a thymus IV is stated to occur in some reptiles, *e g*, snakes In respect of the presence of a distinct thymus IV. as well as in the mode of origin of thymus III from the entire caudal as well as the ventral wall of cleft III, *Trichosurus* exhibits more primitive relations than any Mammal hitherto investigated.

The thyroid would appear to be of composite origin. Its main mass takes origin from a median ventral outgrowth of the pharynx arising in the normal position between clefts II and III, but it is highly probable that the post-branchial bodies also take part in the formation of the lateral lobes The post-branchial body on each side after separating from the fourth cleft comes to lie on the mesial side of the thyroid lobe, and the two become enclosed in the same capsule From the walls of the post-branchial body there arise sprout-like processes which penetrate amongst, and become indistinguishable from, the cellular cords of the lateral lobe It is probable that these processes also give rise to thyroid vesicles.

2 *Fat-tailed Sheep.* *By* Professor J. C Ewart, *F R S*

About fat-tailed sheep one naturally asks, 'From what wild ancestors are they descended, and for what purpose is fat stored up in the tail?' There is no evidence that long-tailed sheep, with or without a store of fat, are descended from long tailed, wild ancestors Three types of wild sheep exist at the present day There are sheep of the Urial (*Ovis vignei*), of the Mouflon (*Ovis orientalis*), and of the Argali (*Ovis ammon*) type

All true wild sheep are characterised by a short tail In the Peat sheep (*Ovis palustris*), which reached Europe in Neolithic times, we have a domesticated variety of the Urial—a short-tailed race (found on Soay, near St Kilda, and in Shetland), with goat-like horns in the female, which is perhaps the best living representative of the Peat sheep In Studer's sheep (*Ovis studeri*), of Copper Age deposits, we have a domesticated variety of the Mouflon—a short tailed race, the males with large curved horns, but the females hornless, which occurs in Soay and Shetland, and seems to be the best living representative of the Copper Age sheep In the short-tailed fighting ram of Nepal, with large spiral horns, we seem to have a somewhat modified representative of the Argali, or of its ally, *Ovis poli* Some fat-rumped sheep with a short tail (*e g*, fat rumped Persian sheep) may be descended from domesticated varieties of the Urial or Mouflon, but sheep with a long fat tail (*e g*, the fat-tailed sheep of Afghanistan) are probably descended from domesticated breeds allied to the fighting ram of Nepal

It is highly probable that as the large inland seas, common in Central Asia in prehistoric times, dried up, domesticated sheep, to have a chance of surviving, found it necessary to store up fat by way of providing nourishment during the long dry season

In some cases fat was deposited to form fat-rumped races, in others to form fat-tailed races The individuals which, by increasing the number and length of the tail vertebræ, provided most accommodation for fat would, in the struggle for existence, have the best chance of surviving, as the aridity in Central Asia increased

It is extremely probable that the long-tailed European breeds, instead of inheriting, as used to be assumed, their long tails from an extinct long-tailed wild ancestor, are indebted for their long and apparently useless caudal appendages to fat-tailed ancestors Evidence in support of this view is afforded by the

fact that the fat gradually disappears when a race of the Afghan type is removed from the arid deserts of Central Asia to Western Europe, where green food is available throughout the year Apart from its coat and its long tail, a Norfolk ram with large spiral horns differs in no essential point from a wild *Ovis poli* ram or from a male Siberian Argali (*Ovis ammon*)

3 *The Life-history of a Water-beetle.* *By* F. Balfour Browne, *M A , F R S E*

WEDNESDAY, SEPTEMBER 11

The following Papers were read —

1. *The Habits of Phyllochætopterus* *By* F. A Potts, *M A.*

The worm whose life-history and habits furnish the subject of these notes is a new species of *Phyllochætopterus* which is found living in shallow water off the coast of Vancouver Island It lives in long creeping tubes of a translucent horny material, which generally possess several openings, each situated at the end of a short branch of the main tube In nearly all tubes there is more than one individual, and sometimes as many as six, but the number of openings to the tube does not correspond to the number of the worms They can change their position in the narrow tubes fairly rapidly, and can turn round and pass each other Circulation is maintained by the movement of cilia on the median segments and the undulatory movements of the abdomen. Those worms which occupy a favourable position protrude their long tentacles from one of the openings, doubtless to assist in the collection of food.

The body, as in most other members of the family Chætopteridæ, consists of three regions the anterior or thoracic, median or branchial, and posterior or abdominal; but the number of segments found in the last two regions varies very greatly It is not unusual to find adjacent to an individual, in which the anterior and median regions are fully formed, a detached portion consisting of abdominal segments (sometimes with a few branchial) In some cases the anterior region of the body has begun to regenerate. Even when this forms quite a minute stump the whole number of thoracic segments may be marked out

There can be no doubt that the tube is constructed in the first place by a single individual, which is formed from a fertilised egg, and that this worm propagates itself by autotomy, the posterior part regenerating its anterior region after detachment Modifications of the tube occur to suit the increasing population An early stage of this phenomenon apparently occurs in the *Phyllochætopterus socialis* of Claparède, the tubes of which each contain two or three individuals of the same sex, but do not appear to branch, and have only a single aperture Claparède suggested that asexual generation occurred here, but was not able to verify this hypothesis So far asexual reproduction in the Polychæts has only been known among the Serpulids (*Filograna*, &c), and it is now found to occur in the Chætopteridæ, a family also showing high specialisation and with tubicolous habits

2 *The Formation of Stolons in Trypanosyllis* [1] *By* F. A. Potts, *M A*

In certain species of *Trypanosyllis* the stolons (reproductive buds) are produced from a ventral patch of tissue extending over the surface of the last segment or two. They are formed in successive transverse rows of seven or eight, and it is probable that from one to two hundred stolons are normally produced by a single individual Proliferation takes place chiefly at the anterior border of the patch, and it is here that new rows are constantly added, pushing

[1] Cf 1902, Johnson, *American Naturalist*, vol 36, pp 295-315, 1911, Potts, *Ergebn u Fortschr d Zool* , Heft 1, Band 3, pp. 14-20.

those already formed backwards, so that the most posterior stolons are the oldest Typically ectoderm and mesoderm alone take part in the formation of the stolons, which thus differ from those of all other Syllids in the entire absence of an alimentary canal, though otherwise completely developed

In *Trypanosyllis gemmipara* from the N W Pacific stolon-formation is accompanied by the rapid addition to the stock of a tail of forty to fifty segments This, unlike the stolons, contains a direct prolongation of the alimentary canal of the stock, but, like them, develops generative products In one case this structure actually developed a head with eyes and tentacles, and separated off as an individualised stolon, differing from the others only in its complete alimentary canal In *Trypanosyllis Crosslandi* from Zanzibar stolon-formation is unaccompanied by posterior regeneration of the stock, but there is, at least occasionally, an ingrowth of endoderm from the ventral lip of the anus, into the dorsalmost stolon of the group

At the beginning of proliferation a cushion of mesoblast arises covered by a thickened layer of ectoblast Each stolon is a centre of proliferation, and the lines of separation are occupied by non-proliferating epithelium The cushion is formed by a mass of connective tissue and muscle-fibres in which occur vast numbers of rounded cells with deeply staining nuclei, often dividing, which enter the interior of the stolons as they form In the earliest stage of proliferation observed (*T Crosslandi*) the body cavity near the region of proliferation was almost filled by leucocytes, which also migrated into the solid cushion It is suggested that they partly serve a nutritive function but also give rise to the greater number of the mesoblast cells The mesoblast does not appear to reinforce the proliferating ectoblast

From the mesoblast of the cushion are formed the gonads, the coelomic epithelium, and the connective tissue, but the muscles of the stolons are directly developed from the longitudinal muscles of the stock, bundles of which may be traced radiating through the cushion of proliferation and entering the stolons Blood-vessels, it must be noted, are entirely absent From the ectoblast are developed the usual ectodermal structures, with the exception of the nervous system, which is formed directly by branches from the ventral nerve cord of the stock growing into the stolons

---

3 *On a Budding and Hermaphrodite Annelid* (Filograna implexa, *Berkley*) *By* Professor W C McIntosh, *F R S*

This annelid has long attracted attention from the coral like masses formed by its agglutinated and slender calcareous tubes, and the symmetry and beauty of the contained animals—which belong to the serpulids Various species have been described by different naturalists, but the chief interest lately has been the very close structural resemblances between the two conspicuous genera—viz , *Filograna*, which has an operculum or lid to its tube, and *Salmacina*, which has none The views of Berkeley, Huxley, Claparède, Keferstein, De Quatrefages, Dalzell, Langenhans, Caius, Ehlers, De St Joseph, Malaquin, and others were considered, and the author's interpretation of the structure of the two groups (with the aid of large diagrams) was given, and after the examination of many examples from the British and other seas, the points of distinction between the two groups were severally dealt with, and it was shown that the presence or absence of an operculum on the branchial stems was not a point on which great dependence could be placed, since in the North—for example, in Shetland, the Moray Firth, and St Andrews Bay—amidst vast swarms of those devoid of opercula a few occurred with them Further, it was shown that these organs (opercula) in this form are exceedingly variable in development, and that where they are absent the tips of the branchial filaments show great susceptibility to growths of a more or less conspicuous character, the largest processes occurring in the Neapolitan form—in which their outline is elongate-ovoid Variability is not confined to the tips of the filaments, for the pinnæ are short, long, or of medium length, according to the age or surroundings of the example The bristle-tufts of the anterior region likewise vary from five to ten pairs, yet throughout the whole series of those with and those without opercula the

structure of the bristles and hooks is precisely the same Both kinds likewise freely give rise to buds, though in regard to the appearance of the male and female reproductive elements in these there is room for further investigation Thus, in the southern non-operculated form the buds show male elements in the front of the posterior region, and female elements near the tail, and after separation the conspicuous reddish ova are soon in evidence, the male elements, however, in some having previously reached maturity Further investigation is necessary in connection with those having numerous small ova (North Sea) and those in which the ova are larger and with trochophores in the tubes

Finally, in forms having such a tendency to vary in plastic organs like the branchial pinnæ and the tips of the filaments, and which have or have not opercula, yet in which the general structure internally and the minute characters of the bristles and hooks do not vary, hesitation is felt in making a separate species of any type hitherto examined

4 *On the Development of the Mesoderm and Head Kidneys of Pomatoceros* *By* Dr. C SHEARER.

5 *The Isle of Wight Disease of Bees* (Microsporidiosis) *By* H B FANTHAM, *D Sc* , *B A* , *and* ANNIE PORTER, *D Sc*

The cause of 'Isle of Wight' disease in bees was discovered by the authors in 1906 to be the minute Microsporidian parasite *Nosema apis* The disease is now known to be more widely distributed and is termed Microsporidiosis

Nosema apis is, in the main, a parasite of the alimentary tract of the bee, but can invade the hæmocoel and multiply therein Spores of the parasite swallowed with food or drink by the bee give rise each to an amœboid parasite, the planont, which parasitises either an epithelial cell of the gut or else reaches the hæmocoel In either case it becomes rounded, grows and feeds for a time, and then commences to multiply The process of multiplication is termed merogony, and the dividing form is called the meront Daughter meronts are formed by various types of binary fission producing clusters or chains Each daughter meront is ultimately uninucleate The meront stage of the parasite is often deadly to the host, when the parasite itself cannot attain its full development, the spore The second stage of the *Nosema* life-cycle, known as sporogony, serves for the transference of the parasite to new hosts The full-grown meront becomes the pansporoblast, which undergoes complicated nuclear changes whereby five nuclei are ultimately produced The sporoblast also forms two vacuoles, an anterior polar capsule and a posterior vacuole in which the polar filament is coiled The secretion of the sporocyst converts the sporoblast into the spore The great power of merogony compensates for the formation of but one spore from the pansporoblast Merogony causes derangement of the bee's digestive processes

The symptoms of Microsporidiosis vary. Inability to fly, crawling, dislocation of the wings, abdominal distension, and 'dry dysentery,' followed by early death, may be noted Warm, bright weather favours the bee, wet or damp aids the parasite Bees weak after hibernation rapidly succumb

Nosema apis has been proved fatal by feeding hive bees, mason bees, and wasps on honey containing *Nosema* spores, some honey being artificially infected, other sets being naturally infected by fæces of former victims, by smearing infected excrement on healthy bees and allowing them to clean themselves, by uniting healthy and infected bees, by housing healthy bees in cases in which infected stock had travelled

In Nature the method of infection is contaminative Hives, comb, capped and uncapped honey and pollen from comb have all been found to contain *Nosema* spores Bees' drinking-places infected with *Nosema* spores have been observed Flowers, water from foliage, and dew from low plants near infected hives all have contained spores Wind can act as a distributor of *Nosema* spores, also ants and wax-moths Some bees can adapt themselves somewhat to the parasite, which forms crops of spores within them Such parasite carriers act as reservoirs of disease

Preventive measures seem of most value in treating the disease The only certain destructive agent for *Nosema* spores is fire All dead bees should be burned. Old comb and hives untreated by a painter's lamp after disease are to be avoided. Weak stocks should not be united. Great care should be exercised in importing bees whether from other places in the British Isles or abroad Liming the soil around each hive is of service Provision of abundant honey and pure water supply, together with scrupulous cleanliness of the hive and its surroundings, are great aids in the prevention of Microsporidiosis

References

Fantham and Porter (1911), *Proc Zool Soc Lond*, p 625
Fantham and Porter (1912), Supplement to *Journ Bd Agric*, May 1912
Fantham and Porter (1912), *Annals Trop Med and Parasitology*, vi, pp 145 214, three plates

6 *Some Observations on Boring Mollusca* By B Lindsay

In view of the part played by the work of boring mollusca as a factor in the process of coast erosion, it is desirable to ascertain the rate at which they remove the material in which they bore But, while we know the size of the holes they make, we do not know how long it has taken to make them, because we do not know with any exactitude the age of the animals we find in the holes

Many attempts have been made to estimate the rate of growth of shellfish, by means of marks where growth has (*ex hypothesi*) stopped during the winter season But the boring mollusca having formed themselves a shelter from the weather, their shells do not, as a rule, show any very definite marks of this kind

But the growth of successive ridges, being intimately connected with the periods of activity in boring, afford some clue to the rate of shell-growth When boring molluscs are removed from their holes and kept loose in a tank for some time, abnormalities in the margin of the shell appear, corresponding to the growth put on during captivity A study of these suggests that there is a connection between lunar or tidal periods and the formation of new ridges, and the study of other bivalve molluscan shells, not borers, tends to confirm this view

7 *The Presence and Absence Theory Unsound* By Dr. James Wilson.

The Presence and Absence Theory originated at the time the inheritance of certain fowls' combs was being studied, and was first used to explain some of the experimental results in that case The experimenters took the view that rose, pea, and single combs are each due to an independent single factor, whereas each is due to two factors *at least* As a matter of fact, it can be shown that there are four factors concerned in the production of each of the combs concerned

Besides, the solution of the presence and absence theory requires two factors to each comb, although this is not apparent until it is discovered that factors are made to work negatively at one time and positively at another, the facts of the case which the theory was set up to explain being otherwise than they were taken to be and the working of the same factors negatively and positively discredit the theory.

But it is unsound on its own merits The following may be taken as the usual statement of the theory 'All observations point to a conclusion of great importance—namely, that a dominant character is the condition due to the *presence* of a definite factor, while the corresponding recessive owes its condition to the *absence* of the same factor' This statement is ambiguous If it means that a long factor turns a short pea into a tall, and that, by the removal of the long factor, the long pea becomes short again, *but that the short pea is still due to the same original cause that made it short before the introduction of the long factor*, there need be no quarrel with the statement further than that it does not state the whole case

But this is not the usual interpretation—probably because of the incompleteness

of the statement above—which is that the long factor is the cause of the long pea and the absence of the long factor is the cause of the short character This makes a cause which is absent do the work of another cause which is present, *but overlooked The absence of the long factor is the cause of the absence of the long character, but it is not the cause of the presence of the short*

The fallacy lies in supposing that a cause which obscures the effect of another cause does something more—namely, that *by its presence* it annihilates the other cause and re-creates it again by its absence If the moon come between the earth and the sun the effect of the sun is obscured, but when the moon passes out of line the light still comes from the sun If a statue be placed upon a pedestal and the pedestal knocked away, is it the absence of the pedestal or the presence of gravity that brings the statue to the ground? As might be expected, the theory when used in analysis overlooks real recessives, and when one or more such turn up without their connection with their proper dominants being discovered, so many factors more than the case can hold are introduced

8 *The Preservation of Specimens for Museums by Simple Immersion* *By* A LOIR, *M D*, *and* H LEGANGUEUX.

For a long time past a formula has been given for the preservation of crustacea without disembowelling This last work is slow, nevertheless, it is employed in museums The formula published is based on arsenic and calcium salt in solutions, with glycerine in an alkaline medium

We modified the formula in preparing directly arsenite of potash (neuter salt) and by adding to it a very weak solution of formalin in sugar, glycerine, and water This process gives us the method of preserving by simple immersion not only crustacea, but jelly-fish, coleoptera, lepidoptera, hymenoptera, fish, and even hedgehog The softness of articulations is complete and gives to specimens the appearance of life much greater than the ordinary method of preservation

The duration of immersion (two to twenty days) varies naturally, not only according to species, but for every specimen, according to its size The end of the operation is known when the preserved specimen is taken out of the bath and put to dry in hot air (35° cent) for two hours, then with a little skill it is easy to see if it is in good condition

For crustacea, lepidoptera, hymenoptera, and coleoptera a bath is quite sufficient For fish it is better to begin by an intestinal washing For the hedgehog we think it is preferable to take out, at first, the intestinal mass, wash the body with formalin water, then fill it with sawdust

Section E—GEOGRAPHY

President of the Section—Colonel Sir C. M. Watson, K.C.M.G., C.B., M.A., R.E.

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

The last occasion upon which the City of Dundee extended its hospitality to the members of the British Association was in 1867, forty-five years ago, and, at that meeting, the President of the Geological Section was Sir Samuel Baker, who had then recently returned from his explorations on the Upper Nile, for which he had been awarded the Patron's Medal of the Royal Geographical Society, and which were of the greatest importance as regards that then little-known river.

In the Address which he gave to Section E, Sir Samuel Baker naturally referred at considerable length to the geography of the Sudan, and to the question of the sources of the Nile, which had been discovered a few years previously by Captain Speke and Captain Grant, when they visited the great lake, named by them the Victoria Nyanza, out of which flows the main branch of the river, the fertiliser of Egypt, which, after a course of more than 3,500 miles, pours its waters into the Mediterranean. He also spoke of the second great lake, the Albert Nyanza, which he had himself discovered, after a long and very arduous journey, though, perhaps naturally, he did not dwell so much on what he had himself accomplished, as another speaker might have done. The words he spoke are well worth calling to remembrance, and, on reading them over, one is struck by the fact that hardly anything was then known of the country through which he travelled, but that, thanks to him and his predecessors, Speke and Grant, the first steps were taken which led to half-a century of steady progress in geographical knowledge, until now the basin of the Upper Nile is fairly well known and fairly well mapped.

To-day I propose to take up the tale where Sir Samuel Baker had to stop, and to give a short *resumé* of the story of the Sudan since those days, more especially from the geographical point of view, but it will be necessary briefly to allude to its history also, for, in this case, as in all others, history and geography are closely united, and it is difficult to understand one without knowing something of the other.

There is a considerable amount of uncertainty in the minds of some people as to what the Sudan is, an uncertainty not without reason, as the word has an ethnological rather than a geographical meaning. The complete word, Balad-es-Sudan, is an Arabic expression for the country of the black people, and therefore includes, theoretically, all those parts of Africa which are inhabited by negro or negroid races. There has, however, been such a mingling of different races that it would be difficult to say to what part of the great continent the word Sudan should properly be applied. But, of recent years, changing from its original ethnological meaning, it has come to be regarded as the name of a more limited area; and perhaps the simplest definition is that it includes all the

country watered by the Nile and its tributaries, as far north as the twentieth degree of latitude, and excluding the Sahara, and the basins of Lake Chad and the Congo on the west, and the districts watered by the river systems which terminate in the Red Sea and Indian Ocean on the east Such a definition does not, of course, altogether agree with the existing political divisions, as it includes the eastern part of Abyssinia, Uganda, and part of the Congo State territory, but these divisions are in no sense geographical, whereas the basin of the Nile is a well-defined region which contains the greater portion of what may be regarded as the real Sudan

There is one point as regards the geography of the Sudan which is remarkable and perhaps unique. In former times it was to a certain extent known, and, in the maps of Ptolemy, and of the Middle Ages, the great lakes, the ranges of mountains, and the rivers flowing from them, are indicated in a distinct, if not very accurate manner But, owing to various causes, this geographical knowledge was completely lost, and the natural features disappeared from the maps Look, for example, at Keith Johnston's Atlas, published in 1843, and you will see that there are no lakes shown, while the Nile to the south of 10° North latitude is indicated as an insignificant stream The Sudan had relapsed into the position of a *terra incognita*, just as it had been in the days of Herodotus, and Ptolemy and the other ancient geographers were regarded as victims of their imaginations

The revival of the knowledge of geography of the Sudan may be said to commence with the travels of James Bruce, who visited Abyssinia in 1770, explored Lake Tsana, and found what he believed to be the true source of the Nile in the River Abai, which ran into the lake from the south He examined the place where the Blue Nile flowed out of Lake Tsana, but was not able to follow its course through the western mountains of Abyssinia, and rejoined it at Sennaar, about 220 miles above the junction with the White Nile Travelling along the south bank of the Blue Nile, he crossed it at the ferry of El Efun, and then went on to Halfaya, north of the site of the present town of Khartum, which at that time did not exist Of the White Nile he says 'At half-past eight, about four miles further, we came to the village Wad Hogali The river Abiad, which is larger than the Nile, joins it there Still the Nile preserves the name of Bahr-el-Azrek, or the Blue River, which it got at Sennaar The Abiad is a very deep river; it runs dead, and with little inclination, because, rising in latitudes where there are continual rains, it therefore suffers not the decrease the Nile does by the six months' dry weather' This is all he says of the White Nile, and he does not seem even to have taken the trouble to look at it, as he reports the point of junction of the two rivers as four miles north of Halfaya, whereas it is to the south of that place He was so convinced that the Blue River was the one and only Nile that he regarded the investigation of the White Nile as unimportant, and shows it on his map as a comparatively insignificant river Bruce's action in this matter is a warning to explorers not to neglect to examine something that does not fit in with their preconceived ideas

At the time of Bruce's visit the origin of the White Nile seems to have been unknown to the inhabitants of the kingdom of Sennaar, a kingdom which had been established in 1504 by the Fung dynasty, which had taken possession of what had been the Christian kingdom of Alwah Soba, the capital of Alwah, was abandoned, and a new town built at Sennaar, which was made the seat of government The Fungs were partly of Arab and partly of negro descent, and their kingdom extended east of the Blue Nile to the foot of the Abyssinian Mountains, and westward as far as the White Nile, beyond which were the independent kingdoms of Kordofan and Darfur At that time there appears to have been little or no traffic on the White Nile, and the marshes of the tenth degree, inhabited by the powerful Shilluk tribes, formed an impenetrable barrier to the south

But, although after Bruce's expedition to Lake Tsana the majority of people seem to have accepted the Blue River as the true Nile, there were some wider-minded people who felt that there was a secret hidden behind the marsh barrier One of these was a certain Mr W G. Browne, who made an interesting journey to Darfur in 1793, and who records in the account of his travels that he had the conviction that the river, of which Bruce had discovered the source, was not the true Nile, and that he considered it a matter of great importance that the

course of the more western river, i e the White Nile, should be investigated, as he could not believe that its source was only two hundred leagues south of Sennaar

Starting from Egypt, Browne travelled with a merchant's caravan from Assiut, by way of the oases of Khargeh and Selima, to El Fasher, in Darfur Here he remained for three years, but was not able to do much in the way of exploration, as he was thwarted by the king and people, and was not allowed to go to Sennaar or to explore the White Nile. He collected, however, from the accounts given him by the natives, a good set of itineraries in Darfur and Kordofan, the first, so far as I know, compiled for the Sudan But his efforts to obtain information as to the source of the White Nile were not successful, and all he was able to learn was that ten days' journey south of a place called Abu Telfan, the Bahr-el-Abiad had its source in forty rivers, which came from the hills of Kumr It seems probable that these numerous rivers were those that form the head-waters of the Bahr-el-Ghazal, and that the people of Darfur knew as little about the Bahr-el-Gebel, as the southern part of the White Nile is called, as the people of Sennaar

But although Browne was not able himself to solve the mystery, his name should not be forgotten, as being one of the first in modern times to realise the fact that the White Nile was the longer of the two rivers His views, however, seem to have met with no support, and Bruce was supposed to have settled the question of the sources of the Nile The great lakes, shown by Ptolemy and the mediæval geographers, were, as I have already mentioned, erased from the map, and the White Nile was left in peace

During the visit of Browne to Darfur the kingdom of Sennaar had fallen upon evil times, as an insurrection, which had commenced during the reign of Bady, ended with the death of King Adlan in 1789, when the Fung dynasty came to an end, and all authority fell into the hands of the tribal chiefs, who made and removed the kings of Sennaar at their pleasure. The internecine wars continued up to the time of the arrival of the Egyptians in the Sudan, and greatly facilitated the advance of the latter

This advance of the Egyptians was due to the policy of Mahomed Ali Pasha, the Turkish Governor of Egypt, who had greatly increased his power by a successful campaign in Arabia in 1812-18, when he succeeded in capturing Mecca and Medina, and made himself master of the country He then turned his attention to the Sudan, and decided to take advantage of the local troubles and to add Sennaar and Kordofan to the Egyptian dominions In 1820 he sent an army up the Nile, under his son Ismail, who took possession of Dongola and the country adjacent to the river, as far as the junction of the Blue and White Niles, and, after seizing Sennaar, marched up the Blue Nile to Fazokl, on the Abyssinian frontier Kordofan was also occupied, and the capital of the new Egyptian province was placed at Khartum, the point where the two Niles met, which took the place of the old capital of Sennaar, but no attempt was made to take possession of the country along the White Nile to more than about one hundred miles south of Khartum So little was that river known beyond this that when Linant Pasha succeeded in sailing up the river as far as the Island of Aba he was supposed to have arrived at the furthest point reached by a European since the first century.

No further advance was made for a few years, but, in 1838, Mahomed Ali decided to try to open up the White Nile, and an expedition under Major Selim, of the Egyptian Army, succeeded in making its way through the marsh district, and in reaching a point about 6° 30′ North latitude on the Bahr-el-Gebel, while another expedition in 1842 got as far as Gondokoro It was thus proved that the marshes were not impenetrable, and trading stations began to be opened up, both on the Bahr-el-Gebel and the Bahr-el-Ghazal. On the former river, however, the traders could not at first proceed further than Gondokoro, as the rapids, which commenced a few miles south of that place, made navigation by sailing vessels impracticable, so the merchants had to establish their depots at Gondokoro and depend upon the natives bringing ivory from the south. To these natives the opening of the river proved a great evil, as the legitimate traders were soon followed by slave-hunters, who carried thousands into captivity, while killing many others By the ill-will thus created the difficulty of exploration was increased In the end, the source of the White Nile was

discovered not from the north, but from the south, when Captain Speke, who, in company with Captain Burton, was exploring Central Africa from the east coast, heard of a great lake lying to the north, and succeeded in reaching the south end of the Victoria Nyanza in 1858 Convinced that he had found the long-desired source of the Nile, he started on another expedition, accompanied by Captain Grant, in 1860, and, after marching round the Victoria Lake, reached Gondokoro in 1863. Here he met Sir Samuel Baker, who had started from Khartum in 1862, in the hope of discovering the Nile sources The information given by Speke and Grant showed that they had forestalled him; but he continued his journey, and in 1864 succeeded in reaching the Albert Nyanza, the second great lake, from which the White Nile derives its water.

Thus, at length, after a lapse of many centuries, the truth of the statements made by Ptolemy and other ancient geographers was justified, and the lakes shown by them were restored to the map of Africa, while the White Nile was proved to be the real Nile, and the Blue Nile was relegated to the position of being the most important tributary

During the period of the travels of Speke and Baker the slave trade had been rapidly increasing, and the traders had practically taken possession of the country, and made themselves independent of the Egyptian authorities in Khartum These slave-traders cared nothing for geography, and had matters remained as they were at that time, it is probable that a State hostile to Europeans would have been established, and all chance of further exploration would have been lost

But in 1869 the Khedive Ismail, who had succeeded as ruler of Egypt in 1863, and had obtained largely increased powers from the Sultan, decided to restore his authority on the White Nile, and appointed Sir Samuel Baker as Governor of the country south of Gondokoro, with instructions to establish Egyptian rule as far as he could to the south of that point But nature fought against Baker, and the difficulty of sailing up the White Nile had been enormously increased by the formation of the sudd, that strange vegetable barrier which at times completely closes the river channel, and he did not reach Gondokoro until two years had elapsed from the time of his departure from Khartum There he hoisted the Egyptian flag, and then proceeded to occupy the country to the south. But he was not successful, as the force at his disposal was quite insufficient, and, though he established a few stations on the road from Gondokoro to Foweira, on the Upper Nile, little effective had been done when he returned to Gondokoro in April 1873 Neither was he able to do much in the way of geographical research, and, greatly to his regret, was unable to revisit the lake which he had discovered on his first journey

In 1874 Colonel Gordon was appointed to succeed Baker, and, leaving Khartum in March, reached Gondokoro in twenty-four days, the sudd, fortunately for him, having been cut through by the Egyptian officials only a month before his arrival in the Sudan Gordon ruled the equatorial provinces until October 1876, and during that time did much to tranquillise the country, as he had a remarkable influence over the natives He moved the headquarters of the government from Gondokoro to Lado, and established a chain of posts along the Nile to Duflé, and thence to Nyamyongo, in Uganda, about eighty miles below the Ripon Falls. He also placed two steamers and two sailing-boats on the Albert Lake to facilitate communication Gordon devoted much attention to the geography of the district, and prepared a map of the White Nile from Khartum to Urondogani, superior to any that had preceded it This map included a plan of the Albert Nyanza, based on surveys made by Gessi and Mason, both of whom circumnavigated the lake Mason reported the existence of the river, now called the Semliki, entering the lake from the south, but was unable to enter it, as the water was too shallow for his vessel

Soon after his arrival at Gondokoro Gordon fully realised the difficulty of keeping up communication with Egypt by the Nile, and requested the Khedive to send an expedition to Formosa Bay, about a hundred miles north of Mombasa, on the east coast of Africa, with the view of opening up a road towards the Nile The route he thought of was a little north of that now followed by the Uganda railway; but at the time he made the proposal the country was entirely unknown, and the difficulties would have been much greater than he anticipated The idea, however, came to nothing, first, because the expedition was sent to the

River Juba, on the border of Somaliland, which was much too far to the north, and, secondly, because it was ordered away by the British Government, which considered that it was encroaching on the territories of the Sultan of Zanzibar

At the time that Gordon was establishing Egyptian authority in the equatorial provinces the Khedive's dominions were being extended by the conquest of Darfur, and the occupation of the province of Harrar, with its port at Zeila, in the Gulf of Aden An excellent reconnaissance of Kordofan was carried out by Colonel Prout, of the United States Survey Department, in 1875, and a reconnaissance of Darfur was made by Colonel Purdy, another American in the Egyptian service, so that considerable additions were made at this period to the geographical knowledge of the Sudan

But soon afterwards there was a serious setback to the Khedive Ismail's projects of conquest Having acquired Massowah, Tajurra, and Zeila, on the Red Sea, he sent an expedition into Abyssinia in 1875, which was cut to pieces at Gundet, on the road to Adua, and another larger force sent in the following year was utterly defeated by the Abyssinians and had to retreat, with great loss, to Massowah Some surveys were made by the American officers on the staff of the Egyptian Army, but these expeditions did but little for geography, and their fate was the precursor of the destruction of Egyptian power in the Sudan.

Colonel Gordon returned to Egypt in December 1876, and early in the following year was appointed Governor-General of the whole Sudan, a post he held for nearly three years, years of incessant labour, during which, much to his regret, he was able to do little for geography; as, though he travelled many thousands of miles through his vast territories, his whole time was occupied with questions of administration He was wonderfully successful in his dealings with the inhabitants, and had he been left alone for a few years, the history of the Sudan would have been different, but he was constantly urged to send money to Cairo, money which he could not obtain without following the example of his predecessors and oppressing the inhabitants This he would not do, and resigned in August 1879, when he was succeeded by an Egyptian Pasha, who revived the old bad customs of the country His appointment led to the result that might have been anticipated, and in 1881 the revolt led by Mahomed Achmed, the Mahdi, broke out, and the Egyptians were driven out of the Sudan Then the country was completely closed to Europeans, and nothing further could be done in the way of geographical discovery until the defeat of the rebels at Omdurman in 1898 Now, fortunately, peace is restored, a peace which, it may be hoped, will be a lasting one

To geographers, of course, the existing state of affairs is very satisfactory, as it will undoubtedly lead to an increase in our knowledge of the Sudan and its resources That knowledge is still very limited, much more so than many people are aware, and there are vast regions which still stand in need of careful examination Maps, especially small-scale maps, are misleading, and convey the impression that more is known than is really known Take, for example, the case of the Blue Nile, one of the most important tributaries of the great river Of this, the head-waters, Lake Tsana, first carefully examined by James Bruce, are fairly well known, and a good reconnaissance of this lake was made by Mr C Dupuis, of the Egyptian Irrigation Department, in 1903, a copy of whose interesting report is attached to the valuable Report on the Basin of the Nile, made by Sir W Garstin in 1904

The course of the Blue Nile from Famaka on the Abyssinian frontier to Khartum is also fairly well known, although not yet accurately surveyed But of the river between Lake Tsana and Famaka, and of its course through the mountains of Abyssinia, our knowledge is most elementary, and it is doubtful whether the line as marked upon maps is correct. Here is a chance for a resolute explorer to distinguish himself by making a really good reconnaissance of this part of the river, and following it carefully from Lake Tsana to Famaka But it would probably be rather an arduous task, and there would be many difficulties, natural and human, to overcome

The question of the Blue Nile is only one of the many geographical problems to be solved in the Sudan The upper waters of other tributaries, such as the Atbara, the Rahad, the Dinder, and the Sobat, and the mountains from which they flow, are also little known, and will require years of exploration, while great areas of the level country of the Nile basin remain unvisited and unsur

veyed. This can be well realised by anyone reading Sir W. Garstin's excellent report already mentioned, in which he gives an admirable summary of the hydrography, and deals with the important question as to the manner in which the water of the different tributaries of the Nile can best be utilised for improving the agricultural capacity both of the Sudan and of Egypt Among other projects with this object he proposes the cutting of an entirely new channel of more than two hundred miles in length, so as to allow the waters of the Bahr-el-Gebel to leave the existing channel at Bor, eighty miles north of Gondokoro, and to rejoin the Nile near the mouth of the Sobat below the sudd district, but, as he justly points out, the country through which this new channel would pass is practically unknown, as the whole of the area lying between the Bahr-el-Gebel, the Bahr-ez-Zaraf, and the Sobat is a *terra incognita*

Sir W Garstin points out that there is a great loss of water from the Bahr-el-Gebel between Gondokoro and Bor, for which he cannot account, and this is another point requiring to be investigated Reading his remarks upon this subject reminds me of the time when I was assisting in General Gordon's survey of the Nile, when on this part of the river, at a point about fifty miles north of Gondokoro, I noticed a considerable branch leaving the Bahr-el-Gebel, and going apparently in a north-easterly direction The native pilot told me that it was reported by the inhabitants to join the Sobat It was impossible to investigate the truth of this statement, which, at the time, seemed rather doubtful, but it is interesting to note that a high authority like Sir W Garstin records that the Nile loses a considerable volume of water near this place

Whether the proposal of Sir W Garstin to make this great canal will ever be carried out is doubtful, for my own part, I am inclined to think that, having regard to the amount of work to be done in the Sudan, it would be better to leave the Bahr-el-Gebel alone for the present The cost of a canal such as that suggested would be very large, and if funds were available it would be better to spend them on a railway from the Sobat southwards Sooner or later the railway, which now runs some distance south of Khartum to the point where it crosses the White Nile into Kordofan, will be extended, and in process of time will reach the Sobat Meanwhile it might be worth while to select a point on the Sobat suitable for a bridge, and to make that point the northern terminus of a line of railway, leading southwards to Gondokoro, and later, on to Uganda Communication between Khartum and this terminus would, for the present, be kept up by the White Nile, which, with the exception of one or two places, is navigable for the whole year

Looking at the question of the Sudan from the geographical point of view, there has been a wonderful increase of knowledge since the last meeting of the British Association in Dundee, but, on the other hand, there is a larger amount of work yet to be done before the whole of the vast area will have been satisfactorily surveyed, and it must be remembered that the Sudan Government has claims of greater importance at present than that of carrying out a complete trigonometrical survey But exploration will no doubt be carried on year by year, and the blank spaces on the map will gradually be filled up Meanwhile we must wish Godspeed to the British officers in the Sudan, who are carrying out a great work of civilisation, and, at the same time, adding to the geographical knowledge of the world

Leaving the Sudan, I would like to allude to a very important geographical undertaking which has made considerable progress during the past year This is the production of the International Map of the World on the scale of $\frac{1}{1000000}$, a project which has been under the consideration of the leading geographers of the important countries for more than twenty years, since it was first proposed at the International Geographical Congress held at Berne in 1891 The question was discussed at succeeding Geographical Congresses, but did not take definite shape until the meeting held at Geneva in 1908, when a series of resolutions dealing with the subject were drawn up by a Committee composed of distinguished men of many nations, which was appointed to formulate rules for the production of the maps, so as to ensure that they should be prepared upon a uniform system.

These resolutions were approved at a general meeting of the Geneva Congress, and were forwarded by the Swiss Government to the British Government for consideration, whereupon the latter issued invitations to the Governments of

Austria-Hungary, France, Germany, Japan, Russia, Italy, Spain, and the United States of North America, asking them to nominate delegates to act as the members of an International Committee to meet in London and debate the question This Committee assembled at the Foreign Office in November 1909, and Colonel S. C N. Grant, C M G , then Director-General of the British Ordnance Survey, was appointed President The proceedings were opened by the Under-Secretary of State for Foreign Affairs, Sir Charles Hardinge, G C M G , now Lord Hardinge, who, in his address, referred to the progress that had already been made with regard to the International Map, and expressed the hope, on behalf of the British Government, that the great undertaking might be brought to a satisfactory conclusion

The main business before the Committee was to settle on the mode of execution of the map, especially as regards the size of the sheets, so as to ensure that adjacent sheets, published by different countries, should fit together; and also to settle upon the symbols, printing, and conventional signs to be used, in order that these should be uniform throughout A series of resolutions, embodying the decisions arrived at concerning these various points, was approved and drawn up in English, French, and German, the first of these languages being taken as the authoritative text As the map was to embrace the whole surface of the globe, the method of projection to be adopted was, of course, a very important consideration, and, after due deliberation, it was decided that a modified polyconic projection, with the meridians shown as straight lines, and with each sheet plotted independently on its central meridian, would prove the most satisfactory.

The surface of the sphere was divided into zones, each containing four degrees of latitude, commencing at the equator, and extending to 88° North, and 88° South latitude There were thus twenty two zones on each side of the equator, and these were distinguished by the letters A to V north, and A to V south This fixed the height of each sheet For the width of the sheets, the surface of the sphere was divided into sixty segments, each containing six degrees of longitude, and numbered consecutively from one to sixty, commencing at longitude 180° This arrangement made each sheet contain six degrees of longitude by four degrees of latitude, but, as the width of the sheets diminished as they approached the poles, it was decided that, beyond 60° North, or 60° South, two or more sheets could be combined Each sheet could thus be given a clear identification number defining its position on the surface of the globe, without it being necessary to mention the country included in it, or the latitude and longitude For example, the sheet containing the central part of England is called North, N 30.

In order to ensure that the execution of all the maps should be identical, a scheme of lettering and of conventional topographical signs was drawn up and attached to the resolutions, and it was decided that a scale of kilometres should be shown on each sheet, and also a scale of the national measure of length of the country concerned As regards the representations of altitude it was arranged that contours should be shown at vertical intervals of a hundred metres, or at smaller intervals in the case of very flat, and larger in the case of steep ground, the height being measured from mean sea-level, as determined in the case of each country, while the levels of the surface of the country were to be indicated by a scale of colour tints, the colours being green from 0 to 300 metres, brown from 300 to 2,500 metres, and purple above 2,500 metres In the same manner the depths of the ocean and of large lakes were to be indicated by varying tints of blue, so as to show intervals of 100 metres In order to ensure uniformity in the scale of colours to be used, a copy of it, as approved by the Committee, was included in the plate of topographical symbols

The whole scheme was thoroughly well worked out, and great credit is due to the members of the International Committee for the manner in which they carried out their difficult task Since the meeting of the Committee in 1909 the preparation of the sheets, in accordance with the principles decided upon, has been taken in hand in several countries, and a number of these have been issued, which give a good idea of what this great map, the largest ever contemplated, will be like These sheets deserve to be carefully studied, and will doubtless be the subject of considerable criticism, as there are several points which seem worthy of examination

In the first place, it is for consideration whether it would not have been better if the colour scheme for representing differences of altitude had been omitted, as it is doubtful whether the advantage of the result gained is commensurate with the increased cost of printing the colours. And one naturally asks, for what purpose is the map intended? Is it for the use of skilled geographers, of whom there are a comparatively small number in each country, or is it for the instruction of ordinary people? If it is for the latter, it is to be feared that the colour scheme will give rise to erroneous impressions Compare, for example, Sheet North, M 31, of France, with Sheet South, H 34, of part of South Africa In the former, as the greater part of the country shown is less than 300 metres above the sea, the general colour of the sheet is green, while in the latter, as nearly the whole of the country included has an altitude of more than 300 metres, the map is for the most part brown This to the less educated man will probably convey the idea that, while France is a fertile country, South Africa is a desert The fact, too, that the darker tint of green represents the lower level and the lighter the higher, while, in the case of the brown, the lighter represents the lower and the darker the higher, and, in the case of the purple, the relative strength of the tints is again reversed, is rather confusing

There is another point as regards the colour scheme which might be noticed, that is, that it is not the same on different sheets For example, the scale of tints adopted in Sheet North, O 30 (Scotland), North, M 31 (France), and North, K 35 (Turkey), do not correspond In the Scotch map the brown colour commences at an altitude of 200 metres, in the French at 300 metres, and in the Turkish at 400 metres There may be some reason for this, but it appears not to be in accord with the resolutions of the Committee Another reason for omitting the colour scheme for altitudes is that it might be better to keep colour work for other purposes, such as indicating political divisions, as there can be little doubt that so good a map as this, when completed, will be largely used for many purposes It might be better that on a map of this small scale only the horizontal features, such as coast-lines, river-courses, railways, roads, and the position of towns should be shown, while to represent height graphically tends to obscure the former

Another criticism I would venture to make is that the resolutions of the Committee appear to have been drawn up on the supposition that the whole world has been accurately surveyed, and no attempt seems to have been made to distinguish between those regions of which the maps are based on triangulation, such as England and parts of Europe, and the countries of which complete surveys have not yet been made As the construction of the map proceeds and sheets are prepared of parts of the world our knowledge of which is imperfect, this want will become more pressing, but it is noticeable even with regard to the sheets already published It is one of the evils of cartography that where anything is shown on a carefully engraved map it comes to be regarded as true, and, if it afterwards turns out to be erroneous, it is not easy to get it altered

The scale of the map, $\frac{1}{1000000}$, appears to have been wisely chosen, as it is sufficiently large to give an adequate amount of detail, while, at the same time, the sheets will not be unduly numerous Of course, for an international map a natural scale was essential, although for national maps a scale based upon the national system of measures is more convenient, as, for example, in the United Kingdom, where the scales of one inch and six inches to the mile are better than scales of $\frac{1}{500000}$ and $\frac{1}{10000}$ would have been They are more suited for the majority of individuals, and an ordinary foot-rule can be used for measuring distances, instead of having to take them off with a pair of dividers from the printed scale on the map.

Looked at from the general point of view, there can be no doubt that the International Map is a most important and valuable undertaking It is satisfactory that such a leading part in the matter has been taken by the British officers of the Royal Engineers and by the Royal Geographical Society

In speaking of this map I have referred to the advisability, if not the necessity, of distinguishing between what is accurately and what is inaccurately known, and this brings me to another matter of considerable interest, the preparation of maps based upon the observations and information collected by explorers in unknown or little-known countries To these explorers, some of whom have not been trained in geographical science, a large amount of detail

shown upon modern maps is due, and it is only a small proportion of the land surface of the globe that has, up to the present, been surveyed in a scientific manner.

It is therefore of the greatest importance that the best value possible should be obtained from the work done by explorers, and this in the past has not always been sufficiently attended to, though during the last few years it is better understood The people who stop at home in comfortable ease do not sufficiently realise the difficulties under which the conscientious traveller works and gathers together information about the country he passes through Formerly, he generally had to work out his own observations and compile his own maps, but now conditions in this respect have greatly improved, and when he brings home his observations, notes, and sketches he can hand them over to some body, such as the Royal Geographical Society, by whom they will be put in shape in a better manner than he could do it for himself One has heard of an explorer in a little-known country sitting up all night after a hard day's work, working out his astronomical observations, and trying to put his rough surveys into shape He would have done better to have gone to sleep and prepared himself by a good rest for the next day's journey In fact, it would be better if an explorer never looked at the figures of an observation after he had recorded them, or read over the notes of his past work, confining himself to recording what he has actually seen day by day as accurately as circumstances permitted, and carefully distinguishing what he really saw from what he thought he had seen, or what he had heard.

It would be easy to adduce instances of the errors which have arisen from the neglect of such precautions Perhaps one of the best known is that I have already alluded to, when James Bruce, a careful explorer, because he had made up his mind that the Blue Nile was the real Nile, passed the White Nile without taking the trouble to examine it, and recorded it as being a comparatively insignificant river Then, there was the case of Sir Samuel Baker, who, having reached the shores of the Albert Nyanza with great difficulty, relied too much on what he was told by the natives, and showed it on his map as extending many miles to the south of the equator But great responsibility rests also upon those who have the task of compiling a map from the notes of an explorer, and the greatest care has to be taken to show only what is really known, and not what is uncertain Geographers, whether in the field or in the drawing office, should always hold up before themselves a standard of accuracy higher than it is always easy to live up to.

Geography under its more ancient name of geometry is, of course, the mother of all sciences, although at the present time geometry has got a more narrow meaning, and is perhaps regarded by some as independent of geography, although really only a branch of it The study of the earth upon which they lived was to the ancient nations the most important of all studies, and it is interesting to trace how astronomy, mathematics, geology, and ethnology are all so interspersed with geography that it is difficult to separate them It is satisfactory to note how from the very first the British Association has always recognised the great importance of geography, since the first meeting of the Association at Oxford in 1832, when Sir Roderick Murchison, so well known to fame, acted as President of the Geographical and Geological Section These two sciences remained united in the same section until the meeting at Edinburgh in 1850, when Sir R Murchison was again the President But, at the next meeting, at Ipswich in 1851, they were separated, and while Geology remained as the subject of Section C, Geography, on account of its great importance, was made the subject of Section E, and the science of ethnology was united with it Sir R Murchison was the first President of the new Geographical Section, and was afterwards President no fewer than six times of Section E, showing the great importance attached by him to the study of the science of Geography May I express the hope that the Presidents of the Section will endeavour in future to follow, however humbly, in the footsteps of that leader of science?

The following Papers were then read :—

1. *The International Map* By Colonel C F Close, *C M G* , *R.E.*

As is well known to all geographers, the International Map was definitely standardised by the labours of an official International Committee which held its meetings in the Foreign Office, London, in November 1909, and issued a report which was published by the British Government, at whose invitation the Committee was assembled

The following countries were represented on the Committee Austria-Hungary, France, Germany, Great Britain, Australia, and Canada, Italy, Russia, Spain, and the United States The Committee was the crowning result of the work of many geographers spread over many years Professor Penck in 1891 first suggested the scheme, it was again brought forward in 1893 by Professor Bruckner, and it was discussed again in 1895, but the most important step was not taken until the meeting of the Geographical Congress at Geneva in 1908, when the delegates of the United States proposed that arrangements should be made to standardise the map, a proposition which was agreed to unanimously

The chief characteristics of the International Map, as defined by the resolutions of the Committee, are uniformity, accuracy, and reliability

First, as regards uniformity, the adoption of the Greenwich meridian and the metre made the scheme a possible one, but with reference to the use of the metre there is a proviso that countries using other national units may add the values of the heights in these units if they desire Whilst dealing with uniformity, it should be mentioned that a certain flexibility has wisely been allowed. Thus, although the normal interval of the contours is 100 metres, in hilly districts intervals of 200, 500, or 1,000 metres are permitted, and in very flat countries intervals of 10, 20, or 50 metres Another important point to note is that although the normal edition is a 'layer' map—*i e* , one in which successive altitudes are indicated by a system of colour tints—it is laid down that other editions may be published without these tints—a reasonable concession to those who dislike layer systems

Next, as to accuracy, M Ch Lallemand, who was one of the representatives of France on the Committee, has worked out the errors involved in the system of projection which has been adopted His report has been published by the sister association in France—namely, the Association Française pour l Avancement des Sciences—of which he was recently President M Lallemand finds as a result of his investigation that 'the errors, whether linear or angular, of the mode of development adopted for the International Map on the 1/1,000,000 scale are *practically negligible*, and can give rise to no difficulties in the assembly of a group of neighbouring sheets These deformations, inherent in the construction, are, in fact, much smaller than the hygrometric deformations of the paper on which the map is printed '

As to reliability, the Committee laid stress on the necessity of obtaining the best information available, and expressed the hope that any country producing a map covering portions of neighbouring States would consult the Governments of those States 'on the subject of the material available, especially as regards the nomenclature ' No one will deny the importance of this proviso, which is being acted upon In order, also, to ensure reliability and to reduce the personal element to a minimum, the Committee adopted contouring as the framework for the exhibition of vertical relief and altitude tints for the principal edition, it excluded hachuring and confined the use of shading to the representation of minor features The governing idea was clearly that the information given on the map should be as definite and precise as possible

The total number of sheets required to cover the whole world, including the oceans, is 2,084 If, for the present, we omit consideration of the oceans, the number of sheets to be produced is equivalent to about 500 'full' sheets—*i e* , sheets entirely representing land This will serve to give an idea of the amount of work to be done

And now for a very brief account of the present state of the undertaking

At present five sheets are actually on sale to the public, one sheet of Northern

France produced by the Service Géographique de l'Armée, two sheets of Scotland produced by the Ordnance Survey, one sheet of Turkey, and one of South Africa produced by the Geographical Section of the General Staff. The latter was chosen to show the system of tints under the most trying conditions In addition it is known that sheets are in course of production by the authorities of Hungary, Italy, Spain, and the United States, and two more sheets of the United Kingdom are being produced by the Ordnance Survey

Most of the countries of the world have expressed their approval of the resolutions, the only adverse official criticism having been received from Sweden. Official letters approving the scheme have been received from the Governments of Belgium, Bolivia, Brazil, Bulgaria, Chile, Colombia, India, Japan, Mexico, Norway, Portugal, Siam, Uruguay, and others The Government of Japan, which sent no delegates to the Committee, has, since the publication of the Report, expressed its approval of, and adherence to, the scheme The International Map is, in fact, well under way

2 *New and Improved Instruments for Geographical Surveying.* *By* E A Reeves

The principal part of this Paper consisted of a brief description of some of the more important improvements in instruments for geographical surveying that have recently appeared.

Among the subjects dealt with were . Recent experiments in the determination; night illumination of distant points in triangulation, lamps for reading various forms of theodolites, Invar tape, latest watches for astronomical observation; night illumination of distant points in triangulation, lamps for reading theodolite angles; Zeiss and other forms of reflecting levels. After referring to the above, which have to do with astronomical observation, triangulation, and levelling, the paper passed on to describe briefly the latest instruments for filling in topographical and geographical details, such as the plane-table and recent forms of telescopic alidades, photographic surveying, and the latest work done by the method; the stereo-plotter; Orel's stereo-autograph, introduction of radium paint for illuminating compasses; the astronomical compass and its use in connection with prismatic compass-mapping, where the local attraction is uncertain. Finally, this section finished with a description of a new night-marching watch, which consists of a simple arrangement fitted to an ordinary watch to enable a traveller to march on any desired bearing by stars at night.

At the end of the Paper was described a set of models of instruments which can be constructed at little cost, but which are sufficient for teaching the principles of geographical surveying and field astronomy in schools. These included a theodolite, sextant and artificial horizon, level, tachiometer, and compass

3 *Geographical Progress in Canada* *By* Dr H M Ami

FRIDAY, SEPTEMBER 6

The following Papers were read —

1 *Notes on British and Irish Itineraries and Road-books.* *By* Sir Herbert George Fordham

In this communication the author endeavoured to establish the value and interest of itineraries and road-books in relation to both geography and bibliography, and to trace their development and characteristics from the first publication of such works in the British Isles, late in the sixteenth century, until the advent of the railway system put an end in the middle of the nineteenth century, for the time at all events, to this species of literature As a preliminary note to

the study of British itineraries he drew attention to the early French publications of this character, which go back at least to as early as the end of the fifteenth century, and of which traces are associated with the religious pilgrimages of the early mediæval period, and particularly to the series of 'Guides' published in Paris by Charles Estienne from 1552 onwards. He reviewed the periods and classification in point of time to which the growth and character of road-book literature can be attributed, and indicated its relation to the historical development of cartographic science, and of exact measurement of surface and distance.

This introduction was followed by a list of publications which can be classed as itineraries or road-books, and which appeared in the United Kingdom: (i) Between 1577 and 1675, (ii) between 1675 and 1798, and (iii) from 1798 to about 1850. The first of these periods has its origin in the travels through England of John Leland (1535-1543), and commences with the itineraries of Holinshed and Harrison (1577), and of William Smith (1588), and the 'Guide des Chemins d'Angleterre,' published by Jean Bernard, in Paris, in 1579, and is, later, illustrated by a series of books founded on John Norden's Tables of Distances (1625), measured by the old British mile, which was in use until the roads were perambulated by John Ogilby in the reign of Charles II. The second period of classification dates from the publication of Ogilby's 'Britannia' in 1675—a work which embodies in a hundred folio sheets of road-maps the results of Ogilby's exact measurement of the principal roads of England and Wales. From that date until the end of the next century a large number of road-books is recorded, including a certain number published in Scotland and Ireland, founded both in form and details on the work of Ogilby. From 1798, the date of publication of Cary's 'New Itinerary,' which was based on John Cary's measurements extending over ten thousand miles of roads in England and Wales, road-books and itineraries became more exact and more complete and artistic, illustrating a third and last period of their development.

The author referred, finally, to a few representative French road-books and maps of the roads of France which threw light on the general subject.

---

2. *From the Victoria Nyanza to the Kisii Highlands.* *By* Felix Oswald, *D.Sc., B.A., F.G.S.*

From Kisumu the author sailed round the vast basaltic mass of Gwasi to Karungu on the east coast of the Victoria Nyanza. The hundred-fathom line lies so close to this coast that the considerable depth of the lake here is probably due to a north-south zone of dislocation. For six weeks last winter he camped six miles south of Karungu, investigating some Lower Miocene deposits and collecting vertebrate fossils, &c., for the British Museum. The country consists of high grassy downs of a dissected basalt plateau, with scattered trees of candelabra euphorbias and spiny mimosas. It is separated by the broad alluvial plain of the Kuja River from the rugged granite heights of the Anglo-German frontier. Here the lecturer observed at close quarters the primitive habits and customs of the naked Kavirondo negroes, a Nilotic race of fine physique and high morality. Thence he marched eastwards up the Kuja basin, mapping the topography and geology of hitherto unsurveyed country, through districts decimated by sleeping-sickness, with a consequent reversion to a state of nature. Crossing the granite range of Gongogongo (the haunt of lions and hyænas) and the gneissic peneplain of Sakwa, he entered the Kisii highlands by the Kuja gorge at Vinyo. This quartzite plateau (6,000-7,000 feet high) breaks off by steep escarpments to the north-west and south-west facing the platform of gneiss and schists (with auriferous quartz) at their foot. A vast intrusion of dolerite occurs between the quartzite and the underlying schists, and yields a very fertile soil in the Kuja valley and especially near the base of the escarpments; here consequently are situated the chief settlements of the Kisii negroes, a Bantu-speaking race, differing greatly from the Kavirondo. The country has been practically deforested by their wasteful custom of clearing the ground for their crops by fire.

Kisii Boma, near the head of the Riana, is the administrative centre (trans-

ferred from Karungu), and the sleeping-sickness camp has also been removed to this healthy district, suitable for Europeans Thence the lecturer marched north-west to the Kavirondo gulf at Homa Bay, leaving the Kisii natives at the Riana River Again crossing the dissected peneplain of gneiss (with intrusions of quartz-porphyry), he entered upon a grassy undulating plain from which conical hills of basalt rise abruptly Between the little trading ports of Homa and Kendu he found gypsum deposits, which probably indicate that at the time of their formation the Kavirondo gulf was isolated from the Victoria Nyanza Denudation has been very active around the abrupt basaltic heights of Ruri and Homa, especially since the epoch when the lake stood much higher than at present The lower contours of the surrounding mountains are rounded, whilst the upper peaks, which have never been covered by the water, are sharp and jagged An investigation was made of the soda-lake of Simbi, which lies in an explosion-crater, and the coastal region west of Kendu was also explored

3. *The Country North of Lake Albert* *By* G W GRABHAM

5 *River Development in Central Scotland* *By* H M CADELL.

5. *The Cañons of the Cevennes* *By* A H GARSTANG

The Cañon of the Tarn was almost unknown even to the French traveller until 1890, when the publication of M Martel's 'Les Causses de Languedoc,' and, the year following, 'Les Cévennes,' drew attention to its majestic scenery and interesting geological characteristics Vast areas in the Cevennes consist of plateaux or 'causses' nowhere less than 2,000 feet high, split up during the course of centuries into different blocks by the rivers that gather in the granite mountains of Lozere-Aveyron On the porous surface the vegetation is ill-nourished and stunted While little moisture remains on the surface, the rainfall is considerable It honeycombs its way through the limestone and collects in innumerable streams, which leap from the rock into the gorges of the rivers and their tributaries The climate is severe—cold in cloud, shadeless in sunshine Descend into the gorges and the change is magical, to the gracious atmosphere of a southern climate and a region of luxuriant vegetation

The Gorge of the Tarn is 38 miles long, and up to four years ago the greater part of it had to be traversed by boat In parts it contracts to a width of less than half a mile between rocks which exceed 1,600 feet in height The valley of the Jonte, a tributary of the Tarn, which joins it at Le Rozier, is, in its proportions, little inferior to the Tarn, and in some stretches shows even more resemblance to the cañon type At a height of 1,000 feet above the Jonte, in the limestone cliff which overhangs it, is the entrance to the Grotto of Dargilan Though it does not compare in extent with the more famous Grottoes of Han, it has the advantage in the beauty and variety of stalactites Half a day's journey further on, in the highlands from which Mt Aigonal rises, is the abyss and cavern of Bramabiau Returning from Mt Aigonal to the Tarn Valley by the Defile of the Dourbie, on the summit of the Causse Noir, we meet the huge collection of limestone rocks called by the natives Montpellier-le-Vieux It may be doubted whether there is a more fantastic example of the effects of atmospheric erosion on friable dolomite in existence

MONDAY, SEPTEMBER 9

The following Papers were read —

1 *Dew-ponds and Mist-ponds.* *By* EDWARD A MARTIN, *F G S.*

The author in this Paper gave an account of some experiments which he made on the Sussex Downs in order to test the truth of the theory that the

so-called dew-ponds of the south of England are kept full, or partly so, by dew A dew-pond is a pond, generally on the chalk downs, which has no visible means of replenishment other than rain, and as such ponds as a rule maintain a supply of water during a long spell of hot weather, when most of the ponds at lower levels have dried up, the conclusion has been drawn that they have been fed by dew, and that this dew has been sufficient to prevent them being dried up The name is quite modern, and even Gilbert White, who wrote about their peculiarity, does not call them by that name It is probable that in the popular mind any form of condensation out of the atmosphere has been regarded as dew, and that really these ponds are 'mist-ponds' As regards the foundations of such ponds there is no uniformity The author found no fewer than ten different arrangements of the bottoms of the ponds Many of them had straw as part of the foundations, but no practical pond-builder contended that this had anything to do with the condensation of dew into the pond Straw is a bad foundation on which to puddle clay or chalk, and must necessarily become damp in the process, and so become a fair conductor of heat In order to test the theory that straw would prevent the heat of the earth from rising and warming the pond after nightfall, two ponds were made, in one of which the puddle was laid direct on the straw, and in the other planks were inserted between the straw and the puddle, in order to give a firm base Experiment went to show that in neither case was there any appreciable effect as regards dew deposition This was probably so because, as pointed out by Dr. J Aitken, such a foundation would tend to make the water take a higher temperature during the day, and this would be in direct proportion as the bad heat-connection was effective during the night The water would not have sufficient time as a rule during the short summer night to become reduced below dew-point

The experiments made only refer to those ponds which have no trees or bushes growing around them which would prevent free radiation It is not denied that there would be considerable drip from trees, &c , which would feed a pond. but this means of replenishment would be of a different nature from that which, it had been supposed, a pond would receive when the grass of downland around was seen to be drenched with dew There may be heavy dews upon the grass, but there may be none whatever deposited in the pond It has been suggested that there may be upward percolation of water from the soil into the pond in dry weather, and the state of the puddle when the pond was dug up seemed to show that to some extent this may be the case On the other hand, there may have been escape of the water downward, for it is probably impossible to make a pond-bottom completely watertight It is found that if precipitation and evaporation were equally spread over the year, a pond which was well laid would never dry up But nine-tenths of the annual evaporation takes place in the summer six months, whereas rain is irregular in its distribution The evaporation would actually empty some ponds in the summer months if there were not some other form of condensation which assisted in overcoming the concentration of evaporation during the droughts The author sees in fogs and mists the factor which tends to keep alive the best-made of the ponds The precipitation of mist into ponds, aided perhaps by silent discharges of electricity, and the entanglement of mist-laden salt-dust in the hollows in which the ponds lie, are believed to be the means by which some ponds maintain a supply of water all through the year, in spite of the great draught which is made upon them by numerous cattle

---

2 *Antarctic Discovery* *By* Sir Clements R Markham, *K C B , F R S* *(Opening a Discussion on the Antarctic)*

The Antarctic work which formed the subject of this Paper was solely that which was sketched out by Sir John Murray in 1893—the exploration of the southern continent It did not refer to voyages of ships in the south temperate zone or a little to the south of the Antarctic circle, nor did it refer to mere dashes to the South Pole

The true Antarctic expeditions, with which alone the Paper was occupied, are those whose main objects have been the exploration of the southern continent, those of Captain Scott, Mr Mawson, and Captain Filchner

The author explained the position of our knowledge when Sir John Murray read his Paper, and the reasons for making the first attempt on the shores of the Ross Sea

The results of the first voyage sent out by the Royal and Royal Geographical Societies were passed in review in some detail

The work that remained for Captain Scott's second expedition was then explained, and reference made to the work of the first autumn and winter, including the very special advantage to physical science of a complete series for four years in one place

Captain Scott's journey to the South Pole secured a complete series of observations for magnetic declination on the way and at the Pole, with a survey by the way and an accurate observation fixing the position. Captain Scott's admirable system, which enabled him to make a journey which is unequalled in recent Polar annals, was explained

The probable geographical work to be achieved by Captain Scott in the coming season was discussed The author then dwelt upon the work contemplated by Mr Mawson and Captain Filchner, concluding with a review of what will remain to be achieved after the return of the expeditions now at work

[For the discussion which followed the above Paper, see *Geographical Journal*, xl , p 541, Nov 1912]

3 *Some Experiences of Southern Nigeria* *By* P Amaury Talbot

Southern Nigeria is divided by the great river running north to south, while transversely it is clearly separated into three belts —

1 The region of lagoons and creeks, of which the Niger delta itself forms half, and which stretches, like some colossal Venetian littoral, along the whole seaboard, so honeycombed with waterways that it is possible to pass from French Dahomey to the German Cameroons without so much as sighting the sea This region is a refuge for natives of the lowest type Its vegetation consists mostly of mangrove and that usual to fresh-water swamps

2 The forest belt, dense save where the size of the population has necessitated extensive clearings From a geographical point of view this region is by far the most interesting, whether as regards the formation of the land itself, its flora and fauna, or the origin, character, and customs of its peoples

3 The northern stretch of open grass-land, approximating both in physical features and inhabitants to those of Northern Nigeria

It is principally with the middle region that I propose to deal, and, since the land of the Yorubas to the west, and that of the Ibos in the centre, is comparatively well known, I would venture to draw attention more particularly to the eastern part, of which the Cross River is the principal waterway Its main tributaries flowing northward are divided by the watershed of the Oban Hills from those of the southward-tending Calabar, Kwa, and Akwa Yafe rivers A little below the fifth degree of latitude comes a line of waterfalls, where the three last-named rivers break down, from the granite and gneiss regions above, to the flat country of sedimentary deposits

Near the falls of the Akwa Yafe occurs a remarkable system of underground caves, through which flow two subterranean rivers

To the north stretch the outlying spurs of the Cameroons, the line of which is broken here and there by an occasional pass

The flora and fauna of the country are remarkably rich

Its principal inhabitants are —

Ododop, or *Korawp*, of typical forest-negro type, who have come over from the Cameroons Each member of the tribe possesses a 'bush' soul, usually buffalo, antelope, or wild boar

Ojo and *Uyanga*, who have trekked from the north in quite recent times and whose ritual still demands human sacrifice

Ekoi, a semi-Bantu people, of high type, with extraordinarily interesting folklore and customs

All these peoples plainly show the influence of the deep 'bush' amid which

they dwell, both in character and beliefs. Magic is the dominant note of their lives. Ancestor-worship, Nature jujus, secret societies, and ceremonies for ensuring protection against witchcraft blend together in one complicated ritual. Yet traces still remain to show that these forest folk once lived in open country, bounded by wide horizons, like the present-day dwellers in the northern grass lands.

TUESDAY, SEPTEMBER 10.

The following Papers were read:—

1. *Exploration in the Sonora Desert of Mexico.* *By* I. N. DRACOPOLI, *F.R.G.S.*

The Sonora Desert is that part of Mexico which is bounded on the north by the International boundary-line, on the west by the Colorado River, on the east by the 111th meridian of west longitude, and which extends south to the head of the Gulf of California and along its coast as far as the 29th parallel of latitude. This large tract of country is singularly little known, though it contains much that is of great interest, both scientifically and commercially. Rising in the north-east to a height of 2,000 to 3,000 feet, and more in Southern Arizona, the country slopes gradually and, to the traveller, imperceptibly, towards the south-west till the coast is reached, and this great plain is characterised by a series of isolated mountain ranges, rising abruptly to an average height of 4,000 feet and more, and from five to thirty miles in length. They usually run in the same general direction, south east to north-west, thus dividing the country roughly into a series of broad and sandy valleys. The mountains, whose geological formation is chiefly volcanic and granite, are rugged in the extreme, with little vegetation as a rule, save cacti, but are highly mineralised, and traces of gold and copper are common in many parts. Round and to the north-west of Adair Bay is a broad belt of sand-dunes, at some points twenty miles in breadth, and the flora and some of the animals found therein are very local in character and are not seen elsewhere. The valleys contain in abundance trees—of which the most common are mesquito (*Prosopis velutina*) and paloverde (*Parkinsonia torreyana*)—shrubs and cacti. The appearance of the country is deceptive and would lead one to suppose that there was water in abundance, but the contrary is the case. Water is never plentiful, and in the majority of cases is non-existent, though there are indications that point to an abundant underground flow. The annual precipitation is about three inches, which falls during the months of July and August, at which time also the heat is greatest. As in all dry countries where evaporation is rapid, the daily range of temperature is very great, there being often a difference of from 40° to 50° F. between the maximum and minimum; 120° in the shade is not at all uncommon in the day time.

The flora of this region has been wonderfully endowed by Nature with means for obtaining and storing water, and its study therefore cannot fail to interest the traveller. The country is remarkable for the great number and variety of its cacti, which form the main source of food to the wild animals and also to the Indians. The latter value them very highly, and once each spring hold a festival in their honour before setting out to gather their fruit.

Southern Arizona and Northern Sonora are inhabited by the Papago Indians. They are a semi-nomadic tribe of Piman stock, and physically are a fine race. Being of a peaceful disposition they have not been much molested, but the coming of civilisation in the last twenty years has not proved an unmixed blessing, for it has brought to them, as to the Yuma Indians, the scourge of consumption and other terrible diseases unknown to them before. They have adopted the clothing of the Mexicans, but otherwise they remain little affected by the coming of the white man, and they still cling tenaciously for the most part to their religion and its many interesting customs. There are many traces of ancient civilisation in the Papago country, and other indications which tend to show that they are not indigenous to the country.

In the south-west of the Sonora Desert, in the mountains that fringe the coast, and in the island of Tiburon live the Seri Indians They form a separate family in themselves, and are quite distinct in religion, language, and customs from all other North American tribes Agriculture is unknown to them, and they live a nomadic life more or less, building flimsy brush-shelters as they go along They depend for their food on hunting and fishing, and various forms of wild fruits, berries, and roots From the local character of their gods and other evidence, it is probable that they have lived in this country for countless generations and are, unlike the Papago, autochthonous.

2 *The Libyan Desert and Ennedi* *By* W J HARDING KING

The Libyan Desert may be taken as stretching from the Nile to the Tibesti Mountains, and from the fertile belt on the Mediterranean coast to the boundary of the Sudan vegetation The map of this district is based mainly upon a few travellers' routes, and the surveys of the Egyptian Government in the Egyptian oases; the remainder of it depends almost entirely upon information derived from natives

The north-eastern portion of the desert is best known It consists of a high barren plateau, below which, in large depressions, lie the chief oases These have been inhabited from very early times They are irrigated by primitive artesian wells, which are supposed to date from Roman times They are very fertile, and produce magnificent dates, besides other fruits and a few cereals The natives on the whole are a feeble race, probably owing to the prevalence of fever In many places the sand-dunes are encroaching on the cultivation The effect of sand erosion on the plateau is very marked, sand-dunes cover large areas in the northern part of the desert The dunes run in parallel belts, and are either longitudinal dunes or crescentic in shape The belts run north and south, converging slightly towards the north

It was formerly supposed that the greater part of the Libyan Desert was covered with sand, but this was found not to be the case A large plateau, starting about twenty miles south-west from Dakhleh oasis, and running west, banks up practically the whole of the dunes South of the plateau is a large sandy plain, rising towards the south The top of a hill in this plain was found to be 2,150 feet above sea level

South of lat 20° N a number of fertile spots are reported to exist West of Kowora the desert is said to be all rock, intersected by fertile valleys The water collects in pools on the rocks during the rains West of Ennedi is a basin, into which the rainfall from the surrounding country drains, forming swamps or pools in the rains, which to a great extent evaporate in the dry weather Ennedi is reported to be full of Roman remains In Ershay Lake there are said to be crocodiles The rock desert ends one day east of Kowora Further east the country is said to be flat and sandy

The valley of the Bedayat is reported to contain many springs, which overflow into pools The Arabs say the rainfall from the east and north sides of the Tibesti range discharges into an old river-bed—the Wady-el-Fardy—which supplies the oasis of Kufa with water and then runs past Farabub, Siwa, and Bahrein to the Nile Another old watercourse—the Wady Howar—is said to receive the wadys that flow north from the Sudan and to run into the Nile valley near Dongola

3 *The Submarine Canyon of the Hudson River*
By Dr J. W SPENCER

4. *Note on some Effects of Climatic Pulsation in a Highland Region*
By Professor J. L MYRES, *M A*

The researches of Ellsworth Huntington and others have made familiar the conception of climatic pulsation, and the effects of such pulsation in compelling the pastoral inhabitants of great grasslands, like those which fringe Central Asia

and Arabia, to migrate into less arid regions during periods of insufficient rainfall The extension of these researches to the Saharan region shows that the causes of such changes of climate are of sufficiently wide influence to affect lands which lie on all three sides of the Eastern Mediterranean It is therefore natural to expect that they will be found to affect also the mountain zone which runs along the north side of the Mediterranean basin from Armenia to the Alps and Pyrenees In this highland region the simplest human groups are found to be maintained partly by rather precarious agriculture, partly by pastured cattle, this cattle-keeping itself depending partly on the possibility of a hay crop If either the corn crops or the hay crops fail the highlanders are forced to maintain themselves by predatory raids on their lowland neighbours, or even by permanent change of abode

In these circumstances any increase of rainfall sufficient to augment the fertility of the great grasslands, and provide full sustenance for a growing human population there, is probably sufficient to cause such wet and cloudy summers in this highland zone as to endanger both the crops and the hay, while at the same time enhancing the fertility of the cornlands at the lower levels and extending southward the possibility of haymaking Thus we should expect to find evidence of emigration from highland centres in the interludes between each grassland exodus and the next Such highland emigration is illustrated in South-Eastern Europe by the Albanian raids on mediæval Greece, the disturbed condition of Thrace, Macedon, and Illyria in the centuries from the third to the first B C, by the 'Dorian Invasion' intervening between the Phrygian and the Cimmerian movements of pastoral grasslanders, and perhaps also by the reduplicated incursion of lake-dwelling folk at an earlier date still into the lowlands at the head of the Adriatic

---

5 *The Position of Geography in Scottish Schools* *By* T S Muir, *M A*

The curriculum in Scottish schools is fixed by external considerations, such as examinations All schools are subject to outside supervision of some kind. Outside interference in methods of teaching is another matter The Scottish Education Department's 'Memorandum on the Teaching of Geography in Primary Schools' contains grave faults The old method of teaching geography is dying out in Scotland, but the new method is meeting with serious obstacles The teaching of geography after the elementary stage is largely controlled by the Intermediate and Leaving Certificate examinations The papers set in these examinations are open to criticism In the Intermediate stage geography forms part of the English paper and is compulsory, in the Post-Intermediate stage geography is separated from English and is optional The result in the latter case is that geography forms either no part or only a very small part of the education of a pupil over fifteen years of age What is the motive which governs the Department in its policy? Subjects are divided into informative and cultural Geography is held to be a cultural subject This opinion is only half true, because geography is not only cultural but is informative to the very end The remedy is to make geography compulsory throughout the whole school course

---

6 *Irrigated Canada* *By* Sir William Willcocks, *K C M G*

---

7 *The Great Barrier Reef* *By* Professor C Hedley

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION.—Sir HENRY H. CUNYNGHAME, *K.C.B.*

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

ALTHOUGH the theories of Auguste Comte as to the progress of the sciences are in many respects open to question, yet he made two contributions of especial value to our ideas on that subject. In the first place, he was one of the earliest writers who maintained that the social and political sciences are subject to laws just as exact, though more complicated, as the laws which govern the physical sciences; and, in the next place, he formulated the celebrated principle of the three phases of thought. According to this view all sciences commence with a theological stage, they pass through a metaphysical stage, and end by becoming positive.

In a primitive state of civilisation man attributes all phenomena to the exercise of volition; in a more advanced stage of thought he endeavours to attribute them to 'virtues' or 'agencies.' The third stage is reached when he ceases to speculate, and uses general principles rather as modes of classifying phenomena than of explaining them. An example may be taken from theories regarding the nature of fire. At first, fire both celestial and terrestrial wherever it occurred was believed to be due to the direct action of a god. Under Aristotle and the Greeks the phenomena of heat, burning, and dryness were attributed to a principle, one of the characteristics of which was a tendency to fly up to the circle of the stars. But in modern times, owing to the labours of the chemists and physicists, it has been explained as a violent motion of molecules. Of its ultimate character we are still ignorant, but the study of heat has passed into a positive stage, in which great progress has been made in classifying its properties and extending our knowledge of them.

The history of ontology is an example of a study which for centuries was in the theological stage, but which emerged from that condition and entered the metaphysical stage chiefly through the labours of the schoolmen. From their time onwards it steadily evolved along the lines laid down by the realists on the one hand, and the conceptualists on the other, until an attempt at a union of their systems was made by Hegel. But even Hegelism is only metaphysical. We know nothing of what he means by his absolute, which might be the god of Averrhoes or Spinoza on the one hand, or the matter of La Mettrie on the other. The philosophy of the absolute is mere metaphysics.

Positive philosophy or science is at best a classification of phenomena; of ultimate causes we can know nothing. Our knowledge, as is finely said by Byron, is but an exchange of ignorance for that which is another kind of ignorance, though immense progress in knowledge of phenomena is made by the transaction.

One of the signs that a science has passed into the positive stage is that it has been subjected to the laws of mathematics. Mechanics, physics, chemistry, and electricity have long since been treated mathematically

Biology has only recently begun to receive mathematical treatment. Politics, economic sciences, sociology, anthropology, and language have, however, hitherto firmly resisted attempts to bring them under mathematical guidance. In some cases attempts have been made, as, for example, when that great mathematician Professor Sylvester endeavoured to formulate a mathematical poetry. Unfortunately he put his theories into practice, but the mathematical poems which he composed were not such as to encourage the adoption of his methods. The above sciences have, indeed, passed out of the theological stage. We no longer ascribe political maxims to the direct commands of God, nor social phenomena to direct Divine interposition. But all the social sciences are for the most part still in the metaphysical stage. The doctrine of the divine right of kings has only disappeared in order to be replaced by the doctrine of the divine right of majorities. Yet from a positive point of view neither of these stands on a footing much firmer than that of the other. 'The duty of obedience to authority' and 'the right of resistance' are in the same condition. 'The right to work,' 'the right to live,' 'the right to a living wage,' 'the right to the vote' are all metaphysical propositions assumed as axiomatic by various energetic writers and speakers, and which are usually advanced with a dogmatism proportioned to the uncertainty of their foundation. Yet on what basis do they rest? One might with equal cogency declare for 'the right of the stronger to destroy the weaker,' 'the duty to improve the race by permitting and encouraging the forcible elimination of the unfit.' Or again, we might argue that animals have a right to be protected against attempts made upon their life or property, and to be considered in any scheme for the promotion of the greatest happiness of the greatest number. This problem is said to have perplexed Bentham in his later years. For by a negation of the doctrine of the immortality of the soul it was difficult for him to see why they were not to be put on a par with man. Or, again, take Proudhon's aphorism: 'Everyone has a right to that which he has made. Who made the land?—God. Then, proprietor, begone.' Even if the major premiss were granted, it is easy to see that the proprietor might logically refuse to give up the land till God came Himself to ask for it, and decline to surrender it to one who had no more share in making it than the person actually in possession. Another example is the metaphysical aphorism that every right involves a corresponding duty, so that if I have a right to do a thing it is the duty of others concerned in the action to let me do it. This axiom seems at first sight to have a certain amount of plausibility. But does it follow, from the fact that I have a right to kill my ducks, that it is their duty to come and be killed? Nor in this case does the reason addressed to the ducks by the girl in the nursery rhyme appear likely to be very convincing to them. Thus also the right to individual property, the right to an equality of enjoyment, the right to an equality of opportunity, the right of an individual to be considered as an end in himself, the duty of an individual to be considered only as part of an organised society, are all metaphysical assumptions having no firm positive basis. Equally baseless is the axiom that wherever the State enjoins a duty, as on a parent to educate his children, the State ought to pay for it. Or that a local authority contributing funds to an object has a right in every case to interfere with their administration. Yet these are mere chance specimens of the political dogmas that have for years been flying about, and which emphasise the undoubted fact that politics and social science have not yet entered the positive stage of thought.

In what stage is political economy? It appears still the battle ground of opposite schools. Some there are who tell us that it has 'gone to Saturn.' But this only raises the question what is meant by going to Saturn? Is it meant that the so-called laws of economics are not laws at all, and that the whole pretended science is built on false foundations? Or is it meant that those engaged in the practical politics of the country have resolved to legislate in defiance of the laws of economics, and to settle the problems of free trade and protection, the taxation of fixed and movable property, and the regulation of wages as though these problems were not subjected to any natural laws at all?

The latter position would, of course, be particularly dangerous if it turned out that there were laws, and that those laws were being ignored. For example,

there is a school of biologists who contend that acquired characteristics are never inherited, and that therefore all education and improvement of environment can only be useful inasmuch as they promote the generation of the best types—but that, unscientifically used, these and other means of improvement may, by promoting the survival of the most unfit, only damage humanity. The truth or falsehood of this statement is no concern of this Section of the Association, only one may be permitted the remark that, if it is really a law applicable to the human race, and if it is ignored, it seems most probable that the law will remain here on earth, and that it is not the law, but the race that ignores it, which will go to Saturn Or, to take an example more directly connected with political economy, it is alleged by the students of that science that there are certain laws which regulate wages They are not altogether in agreement upon the laws, still less upon the mode of expressing them, or upon the modifications which are necessary to make them true This is only natural in a science that is only just entering upon a positive stage But I suppose most economists would agree that (provided suitable meanings are given to the words) 'Wages in a free market depend upon the demand and supply of labour'

A Legislature, wishing to remedy social inequalities and evils, might resolve to render the market no longer free—to impose a minimum wage, or to put a tax upon wages, or in other ways to regulate them by statute And legislation might go so far as to render wages wholly dependent on scales fixed by authority or by custom Or, again, a powerful combination, either of employers or of workmen, might unite to fix rates of wages and render it impossible in practice for any other rates to be paid Systems established by these means might be wise or foolish, beneficial or injurious But could it be said that the authors of them had succeeded in sending political economy to Saturn? Certainly not They might have rendered inapplicable that chapter of political economy which deals with price as fixed by exchange in a free market, but only to bring the case under the next chapter, entitled 'Price as fixed under conditions of monopoly' The political economy would be there surely enough, with its laws, and with their consequences for those who ignore its teachings

I am not, mind, arguing against such attempts Man is a social animal, not merely an individual unit, and it may be wise and desirable that certain of his dealings should be regulated by conditions depending on legal regulations rather than on the free play of demand and supply I only point out that if political action be taken in the field of economics such action will, whether the authors of it wish it or not, be governed by the laws of economics, and those who purpose such action must consider what effect it will have on the flow and investment of capital, the demand for commodities, and, in fact, duly take into account the whole problem For, if they do not, it is not the laws of supply and demand that will go to Saturn Again, before settling a scheme of taxation we ought to study the cases in which a tax levied on one class falls on another, as, for instance, a tax intended to be paid by landlords which really falls upon their tenants, of taxes levied on tenants which fall on their landlords, of taxes levied on producers that can be shown ultimately to fall on consumers, and of taxes levied upon commodities that can be shown to fall on the workmen by whom they are produced For a tax often resembles an arrow shot into the air, though apparently aimed in a definite direction it may fall one knows not where, obedient to the laws of the incidence of taxation, just as an arrow in its flight is subject to the inflexible laws of air resistance, friction, and gravity Or, again, when we prohibit work of children or young persons, to whom such work is detrimental, we must consider not only one side of the question, but we must also take into account the loss that may ensue in wages, and the consequences to the nutrition of the family, and also indirectly to the growth of population.

In fact, in all these and similar cases, unless we possess the power of making the sun and moon stand still in their courses, we must have regard to the operation of natural laws, from which we can no more escape than we can from the air in which we breathe

I may perhaps pass by the criticisms or even attacks on political economy by those whose schemes of action appear to contravene its principles. It has been called a 'dismal science' But to a bankrupt, arithmetic is a dismal science,

while to a successful trader it may be a source of daily satisfaction Sciences cannot be dismal or wicked, it is only men that can be joyful or desponding, or good or bad

Having thus endeavoured to the best of my ability to protest against the idea that economics is not a science, but a mere collection of copybook aphorisms that may be used at random like quack medicines, I should like, with your leave, to endeavour to establish its claim to come among the exact sciences by the surest test that can be applied—namely, its capability of being demonstrated by means of geometry and mathematics

I know that here I touch on delicate ground I fear that there are many to whom the very name of geometry is repellent The cause of this generally is that in their youth mathematics was presented to them in a totally indigestible form It was like a vegetable diet is to a cat—the intestine was unfitted to assimilate it I would, however, ask such persons, if any of them be here, to exercise their sense of fairness How many boys who are totally incapable of comprehending any poetic idea are subjected to a steady course of English poetry in the Board Schools, and of Latin poetry in the public schools The process is painful, but it is believed to do them good Seeing, then, that I am, so to speak, in the pulpit for a short time, I will ask those who dislike mathematical reasonings patiently to listen in their turn while I try to expound the doctrines of supply and demand in a geometrical form—a form familiar, I have no doubt, to many of my audience, but very useful to illustrate my present theme, a form first designed by Cournot, but subsequently developed by other workers

I will commence by saying that for the comprehension of this method no previous acquaintance with mathematics or geometry is necessary One can

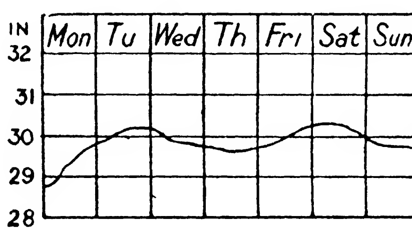


FIG 1

work straight from first principles, and this mode of considering the problem has been so helpful to many persons that I believe it will find favour in the eyes even of opponents. Moreover, in so far as it is correct, it certainly helps to prove the proposition with which I started, that economics may claim to have entered upon the positive stage

Everyone in this room is no doubt acquainted with the machine known as a barograph or registering barometer There is one on the table It is constructed as follows A vertical cylinder covered with white paper revolves once in a week A light arm is hinged on to a series of hollow elastic circular chambers, from which the air has been pumped out As the pressure of the atmosphere varies, the air chambers dilate and contract, carrying the arm with them The arm carries a pen which marks with a dot on the paper the height of the barometer at any time. As the paper moves the dot is drawn out into a line, which gives a continuous record of barometric variations This diagram is a picture of one of the records.

Now, a little consideration will show what a useful diagram we have here If we were to attempt to give the information contained in it in words we should have to say something like this. On Monday at 0 A M. the barometer stood at 28 8 inches, during the morning of Monday it rose until about 2 P M, when it remained stationary for three hours It again steadily rose in the evening, until at midnight it stood at 29.9 inches (fig 1) On Tuesday it still continued to rise till midday, when it again experienced a fall, &c, &c Or, if

the same results were put into arithmetical form, we should have quite a column of figures

But this diagram shows us the height of the barometer at any time, and all its fluctuations Its life-history for the week and the law of its variations are obvious at a glance, in a way which no words could convey to us So great are the advantages of this method that barographs are printed in many of the newspapers

But the use of such curves is not confined to the registration of atmospheric pressure or temperature They may be used for all purposes Thus, for

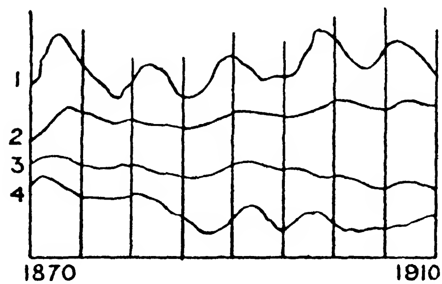


FIG 2

example, we might have a curve indicating the variation in successive years of the number of marriages per head of the population

Line 1 (fig 2) shows the proportion of marriages to population from 1870 to 1910 The advantages of this synoptic view are obvious But they become more obvious still when we add other curves For instance, line 4 shows the price of wheat in various years, line 3 the price of coal, line 2 the average of money wages, and line 1 the number of marriages per head of the population A simple inspection shows that these curves rise and fall sympathetically, and proves beyond doubt that the facts they represent are causally connected

How eloquently this diagram represents, on a space that in a printed book may be three inches square, a series of relations which would take three or four pages to describe even imperfectly in words And would any description in words enable us to follow the changes like this diagram? The diagram, in fact,

FIG 3

plays the part that maps play in geography and when duly appreciated becomes as valuable as maps of countries

We may use similar diagrams in the exposition of economic facts It was, however, reserved for Cournot to show that the use of curves might go further still Not only might they be used to display statistical facts, but they might also be used to solve problems I will endeavour to illustrate this very ingenious and interesting development

It is a well-known fact that in certain departments of industry the cost of making an article increases in proportion to the number produced The growth of corn is a familiar example of this principle The principle depends on two

facts (1) that corn can be grown in some places with a less expenditure of capital and labour than in others, and (2) that the quantity of the more favourable land is limited Whence it follows that growers will first have recourse to the most fertile land, afterwards to that which is less fertile If we were acquainted exactly with the economics of corn-growing we could represent this state of things in any country at any given time by a curve like a barograph

Along the line OX (fig 3), instead of the progressive days of the week, we should mark off successive quantities of corn, and the vertical height of the curve above any given quantity would represent the price per quarter of production

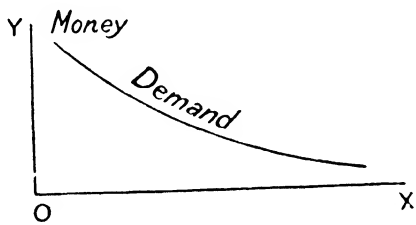


FIG 4

of that part which was produced at greatest expense Thus, the cost of production of the first and most easily grown quarter would be, say 18s, of the next 18s 1d, and so on And it would be evident that the total cost of the whole of the wheat grown would be obtained by adding all these prices together—that is to say, by the area of the curve OMBA, for an area is but the sum of all its constituent parallel lines, just as the total of a bill for goods is an addition of all its items

Let us now dismiss this corn-growing graph from our minds and turn to another side of the question Let us consider the various prices which consumers would give for various quantities of corn if they could get these and no more I do not mean the market prices of the quantities, but what might be called the famine prices, which they would give rather than not have the corn If we draw a corn-consumers' graph it will obviously be a descending curve, for the more they can get the less they will value successive portions In fact,

FIG 5

if the supply of corn were unlimited the surplus would be used first to feed animals, then to consume as fuel, then as manure, and at last have to be destroyed as a nuisance

The curve would be of the form shown in fig 4

The contemplation of these curves of corn will no doubt suggest the question whether if we had them both we could tell what the market price would be For it seems obvious that if we know all the conditions, both of demand and supply, we ought to be able to foretell the market price This is the case and can be easily done All that is necessary is to superpose the curves, as is done in fig 5

We then see at once that PM must represent the market price of corn per

quarter at a given epoch, and OM the quantity produced in a standard time For if more than OM were grown it could only be sold at a loss, if less the growing of corn would produce an abnormal profit, which would soon cause an expansion, so as to bring the quantity grown and sold up to the maximum that could be profitably produced.

These diagrams have therefore done more than present a state of facts; they have solved a problem, just as could be done by a pair of algebraic equations.

Moreover, other illustrations can be derived from fig 5 By drawing the series of lines shown in fig 6 meanings can be given to various parts of the

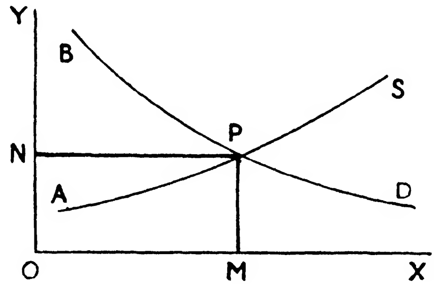


Fig 6

diagram The area NPMO represents the total price paid for the corn; the area APMO represents the total cost of growing, the area APN, which is the difference between them, represents the surplus profit obtained from the use of the better lands, or, in other words, rent, the area BPMO represents the total enjoyment the consumer derives from the corn, expressed in terms of money, and since NPMO is the price he pays for it, BNP is the surplus enjoyment he gets by obtaining corn for less than he would have given for it had there been a famine

Let us go a little further Suppose that a tax were laid on corn, and that all corn grown in a country were subject to an excise duty like that now levied on the manufacture of spirits Suppose the duty were 5s a quarter, and, to simplify

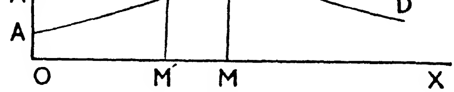


Fig 7.

the problem, suppose no corn came in from the outside Then the curve APS (fig. 7) would be pushed upwards all along its length by 5s, and assume a position A'P'S' And notice that the price would rise not by 5s, but by some amount rather less than 5s For M'P'—MP must always be less than the upward movement of the curve APS. Again, the rent would be decreased, for the area N'P'A' is less than NPA The amount grown would decrease from OM to OM' The proceeds of the tax would be OM' times five shillings, and the consumers' surplus of enjoyment would have considerably diminished This is all obvious enough if you look at the curves. But I want to ask whether,

without a curve, you could have got all that so quickly by logical cogitation? I agree it could have been done by hard thought, but what a help the diagram has been in thinking it out It is like drawing a genealogical tree when you are thinking out some complex problems of family relationship A simple inspection of the figure also shows that an *ad valorem* tax on rent would not increase price or diminish production.

Again, what is a monopoly? A monopoly is simply a power of stopping production at a point short of that which it would reach under conditions of free production, sale and distribution You can stop production by means of statutes regulating quantities produced, or by combinations to limit production, or to limit the supply of labour produced, or by statutes regulating the employment of capital, or by statutes fixing minima of wages, or in various other ways If you exercise the power, then the state of things shown in fig 8 comes into play The quantity produced is reduced to OM′ The price rises from PM to P′M′, the surplus producers' profit (including rent) rises from ANP to AQP′N′ So that profits, interest, and wages increase, but the consumers' surplus enjoyment goes down from NPB to N′P′B The limitation of output plays a far larger part in the regulation of prices than is commonly supposed Those who are engaged in the manipulation of the meat trade, and the bread trade, and the petroleum

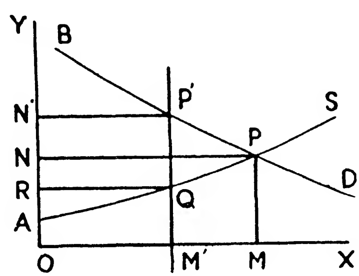


FIG 8

industry, the supply of machinery or other articles, do not usually advertise the means they have taken to limit supply, nor do trade unions publicly descant upon the means they adopt to limit the labour of adults or apprentices It is no part of our business here to discuss the necessity or the legitimate limits of such limitations All that I am here to do is to show how useful diagrams are in explaining their effects

The monopoly controller seeks, of course, to make the area AQP′N′ a maximum, arranging his price just in the way a milliner would do who had to cut the biggest square she could out of a remnant of cloth How much reduction of output and increase of price will the market bear? is the question that all monopolists present to themselves

I could go on with these curves through a great variety of questions They become especially interesting where applied to show the effects of tariffs upon export and import trade, but I must forbear

My principal object has not been to introduce to the notice of the audience a subject already known to many of them, but rather to use it as an illustration of the truth that national economics is subject to laws—laws which, though complicated, are as exact and unfailing as the laws of physics, chemistry, or engineering, and which, if neglected by political engineers, will as certainly bring the State to ruin as the miscalculation of a mechanical engineer in designing a boiler, or of a civil engineer in designing a bridge Whence, then, instead of consigning economics to Saturn, let us study it, not in a metaphysical or Aristotelian manner, using question-begging epithets, or, on the other hand, in the manner of some moderns, as for example Ruskin, by replacing reason by sentiment, but let us approach it in the spirit of positive science

The following Papers were then read —

1. *Federal Government*

By the Right Hon HERBERT SAMUEL, *M A* , *M P*

The principle of federation has made great strides in the modern world Almost half the populations belonging to the white races live under federal constitutions The division of powers between the central and the provincial authorities shows great diversity, but the common feature, which is the defining mark of all federations, is the co-existence of a central authority, acting on behalf of the whole State in external affairs and in such internal affairs as are held to be of common interest, and of local authorities with considerable powers of legislation and administration.

For centuries the movements of constitutional change have been in the main towards greater centralisation The conclusion is often drawn that the natural evolution of States is in that direction, and that any tendency to create, or even to retain, powerful provincial institutions is retrograde But this is a false generalisation The vast area of many modern communities would often make centralisation injurious if not impossible To abolish the local Legislatures of the United States, for example, would not be a measure of progress The continued existence of the British Empire has only been possible through the decentralisation of its government Considerations of local patriotism also enter Germany, with twenty-five Legislatures, is not weaker than France with only one, and would not be made stronger if she attempted to suppress the autonomous institutions of her component States When a number of small States federate they show no tendency to carry centralisation further and to amalgamate

British statesmanship has to consider the needs both of the United Kingdom and of the Empire The Constitution of the United Kingdom is neither federal nor unitary There are separate judiciaries in England with Wales, in Scotland, and in Ireland, the House of Lords having the characteristics of a federal court of appeal The executive also is largely decentralised, Scotland and Ireland have their own Ministers, and of the fifteen Cabinet Ministers who deal with domestic affairs only four exercise functions over the whole of the United Kingdom The Legislature is in the main unitary, but shows several traces of federalism The legislation which it passes is largely decentralised, nearly one-half of the statutes applying only to parts of the United Kingdom How far these conditions are satisfactory is too much a question of controversy to be discussed here, but there are reasons for holding that the Constitution of the United Kingdom is over-centralised, and should properly develop in a federal direction

The Constitution of the British Empire, on the other hand, is clearly under-centralised. The only organs which serve equally all parts of the Empire are the Monarchy, the Judicial Committee of the Privy Council, and the Imperial Conference The Committee of Imperial Defence may develop into another But the populations of the outlying parts of the Empire have no formal share in its sovereignty It is unlikely that this can be the final shape of the Empire's Constitution, but the creation of any federal institutions with executive and legislative powers is a task surrounded by formidable difficulties It may be that, as a stage in development, there will be formed a federal union between Governments, such as existed in Switzerland, in the United States, and in Germany at certain periods in their histories, the central authority having no direct relation with the citizens of the component States. However this may be, it is clear that systems of greater elaboration must be devised to meet the complexity of the problems both of the United Kingdom and of the Empire, and in this development the principles and methods of federalism must play a leading part.

2. *Discussion on 'The Great Illusion.'*

(i) *The Economic and Moral Factors of International Polity.* *By* NORMAN ANGELL.

Criticism directed at the establishment of a sounder European polity, which shall be the basis of co-operation between the European nations, has shown of recent years a curious change of position. Until a year or two since, the efforts to arrive at a European policy were generally criticised, on the ground that they were the outcome of a sentimental idealism which disregarded unduly the conflicting interests of men; they represented the idealism of those who refused to face the hard facts of a selfish world. Recently this position has been almost entirely abandoned, and efforts towards international co-operation are now criticised as being too purely materialistic in motive, and as overlooking the moral differences of nations, which we are given to understand must always stand in the way of their co-operation.

It is impossible to separate in any absolute fashion the moral and economic motives of men: to succour the widow and the orphan, to feed the hungry, to clothe the naked, and to care for the sick are, admittedly, moral motives when they are part of charity. Why should they cease to become moral when, instead of accomplishing these ends through charity, we attempt to accomplish them through the scientific organisation of a better human society?

The development of ideals shows a distinct narrowing of the gulf which is supposed to separate moral aims and those of self-interest. Early ideals, whether in the field of politics or religion, are generally dissociated from any aim of general well-being: early political ideals are concerned with personal allegiance to some dynastic chief, the well-being of the community not entering into the matter. Later, the chief must embody in his person that well-being, or he does not achieve the allegiance of the community; finally, the well being of the community becomes the end in itself, and the altruism of the mass has become self-interest, since self-interest of the community for the sake of the community is a contradiction in terms. Early religious ideals show a like development: a religious ideal which centres upon a sterile life at the top of a pillar or upon a bed of spikes has no longer any appeal. Even religious ideals are put to the test of whether they make for the improvement of society; if they do not, if it could be shown that a given doctrine made for the disintegration of society, the verdict of most modern men would be against it.

Is it better that differences should be settled by discussion, reason mutual adjustment, or by physical force? Does the duel settle the question out of which it arises? Can the moral problems of mankind be advanced in this way? If not, war stands condemned on moral grounds. Men are entitled to defend their possessions, moral or material, but that does not get to the bottom of the matter, since unless one party attacks there is no necessity for defence. The whole question is what should be the attitude of European nations, as a whole, in this matter. On wide questions of policy there is no such thing as the English idea, or the German idea, or the French idea; the existing situation is the outcome of what Newman called 'the European mind,' just as the general decision no longer to employ force in the domain of religious belief was the outcome of a general European attitude.

No considerable intellectual movement can possibly be confined to one country: that was impossible three centuries ago, even before the day of cheap books and instantaneous communication.

The solution of the whole armament problem depends upon the advance of European ideas on the question of international relationship. It is not a question of accepting fatalistically without effort an existing condition: what exists depends on us; it is not something fixed outside our acts and our volition, but the reflection of those acts.

(ii) *The Economic Basis of Universal Peace—Cosmopolitan or International.* *By the* Ven. Archdeacon CUNNINGHAM, *F.B.A.*

Twenty-one years ago, as President of this Section, I argued that cosmopolitan economic forces were gradually breaking down national exclusiveness in every

part of the world As a broad generalisation it seemed to me true that, just as municipal economic life had been absorbed during the later Middle Ages in national life, so national life, both as regards capital and labour, was likely to be absorbed in cosmopolitan economic life Mr Norman Angell has put that argument much more effectively by showing how closely the prosperity of each nation is, through the credit system, intertwined with the prosperity of other countries I am, however, now inclined to think that my forecast of cosmopolitan economic progress and my disparagement of nationality as a factor in economic life were mistaken

However fluid the active elements of economic life may be, there are elements of fixity to be taken into account if prosperity is to be stable There must be the organisation of government, within a definite area in which its control is recognised, if men are to pursue their avocations in security, and coercive authority must lay down the limits within which private interest can be allowed free play and can be rightly trusted to bring about public good National organisation, with a naval and military side, is the most convenient means for giving fair play to native races, and for exercising police control throughout the world National organisation can do much to promote economic prosperity within a country, by guiding the direction of capital, and coercive authority is being called on to control the action of trusts in America and of trade unions here National authority may be utilised not only to put down abuses, but to foster the permanent material welfare of the country

We all recognise that there must be a firm economic basis, on which the police of the world, and peace between highly developed countries, may be based; and the crucial question is whether this can be best secured by (1) a *cosmopolitanism which undermines national economic life*, or (11) *by an internationalism built up out of a group of strong and vigorous nationalities*? The study of British commerce at the present time is of great assistance in deciding whether the present trend of affairs is in favour of cosmopolitanism or of internationalism Great Britain alone among the countries of the world has made herself the exponent of economic cosmopolitanism if she is advancing more rapidly than countries which rely on nationalist organisation, then the cause of cosmopolitanism is advancing, but, otherwise, it appears that economic nationalism still has a future before it So far as I can judge with reference to Great Britain and her commercial rivals, and with reference to different branches of British trade, the success of economic cosmopolitanism, on which the hopes of universal peace are commonly based, is very doubtful The question concerns not only the material basis of peace propagandism, but its moral influence Peace propagandism has been inclined to disparage the 'blind dogma of patriotism,' but if this movement could link itself with patriotic sentiment it would gain in force The cause of peace both among civilised and uncivilised peoples would prosper if it lost its anti-patriotic character and came to rely on the influence and the relationships of great nationalities It is important that the people of any land should value the sense of national independence, it is well for them to attain a sense of national mission Success or failure in the art of war depends on conditions that lead to success or failure in other arts, the benefit to character lies, not in the fighting itself, but in the possession of ideals for which the citizen feels that it is worth while to make a sacrifice It is good for any man to be able to draw inspiration from the past of his country and to cherish ideals for its future

FRIDAY, SEPTEMBER 6.

Discussion on Labour Disputes.

(1) *Methods of Industrial Peace*
By Professor S. J. Chapman, *M.A.*, *M Com.*

The first important point to notice is that it must always be very difficult, if not impossible, to enforce any course of action upon groups of people who are associated in large numbers for a common economic purpose. For success in such

a country as England of any method of industrial peace, whether in the form of arbitration or not, the consent of the interested parties is essential. The experience of New Zealand and Australia would seem to necessitate qualification of this statement, but circumstances there are very different from circumstances in the United Kingdom, and even there the prohibition of striking and locking-out has not been observed without exception. Needless to say a disregard of a law which is suffered without penalty weakens the force of the law and has a cumulative effect.

The following methods of industrial peace may be distinguished:—

(1) The method of settling disputes through the judgment of an impartial arbitrator.
(2) The method by which settlement is brought about with the consent of both parties through the mediation of persons acquainted with the points at issue. This is commonly known as the method of mediation or conciliation.
(3) The method of bringing in public opinion as a third factor through the investigation of disputes and publication of results.

Quite apart from the difficulties connected with compulsion already noticed, arbitration is likely to prove, in an industrialised country like England, a very defective plan, in the first place because the award may be unsatisfying to one or both parties, and, secondly, because the arbitrator will find it exceedingly awkward to get the kind of evidence from which he can deduce the right result. Nevertheless it is better that small disputes should be settled in this way than that cessation of work should supervene, and it is better also that one or both parties should suffer slight dissatisfaction than that an industry should be convulsed by industrial warfare for a lengthy period. The most hopeful method for English conditions would seem to be that of conciliation, the obligation to intervene whenever there were prospects of success being imposed upon some public office, panel, or official. This is the policy of the English Act of 1906, and of the strengthening of that measure by the step taken in 1911. In certain cases the method might be supplemented by the third method distinguished above, which is the outstanding feature of Canadian experiment. And recent events have shown that in special cases a more drastic handling of disputes may be requisite. In connection with the problem of industrial peace, above everything it is important to realise that action at the present time must be tentative and undoctrinaire.

(ii) *A Consideration of some of the Causes affecting Prices and Wages in the past Forty Years.* By Sir FRANCIS WEBSTER.

Is the present rise of prices 'probably due to the enormously increased output of gold'? This would be a facile solution of a difficult problem. Bimetallism in another garb. Unrest as affected by it. Scarcity of gold in the eighties and nineties is not proven as the cause of low prices. Other possible causes. Acceleration and cheapening of transit. Consequent increase of effective stocks of commodities. Consequent decrease of price. Effect of labour-saving in production. Increased financial efficiency. Lower prices counteract lessened production of gold. None of the usual signs of scarcity is visible. Long continuance of peace after 1870. Consequent feeling of security. Effect on gilt-edged securities. Arguments and predictions of bimetallists. These are disproved by events. Advantages of low prices to this creditor country. Speculation as to a possible effect of Protection on prices. Wars break the calm, and downward course of prices is arrested. Effect of war on prices of commodities and of prices of gilt-edged securities. Security begotten of long peace is lost. Warlike expenditure still growing. World's expenditure on luxuries also growing. The accumulated plenty of thirty years' peace is trenched upon. Surplus is consumed. Consequent return of prices to basis of the seventies. Celerity with which stocks of commodities can now be drawn on. Growing wants of civilised communities. Growth of national and of private expenditure. Threatened rapid alterations of prices, their danger. Effect of high prices and active trade on gilt-edged securities. The fall in Consols is not so great as the advance in price of money. The time is approaching when these conditions

will be reversed Return to conditions prevailing in early seventies Danger of this position. Awkward position of wages High prices mark scarcity, not plenty. Scarcity and high wages are incompatible Ameliorating factors High prices and high wages in a protected country are not the same thing as in a free-trading country They are caused artificially in one, naturally in the other Difficulty of existing circumstances Difficulties of manufacturers Manufacturing is one of the least remunerative of all occupations requiring outlay of capital Contrast with other occupations Reasons of poor average remuneration Increasing burdens piled on this unremunerative occupation Effect on wages, wages are growing less elastic Questions of minimum and maximum wage, both impracticable Some causes affecting various wages Benefits of labour organisations to labour doubtful Benefit to labour organiser not doubtful, labour organisation is a new outlet to ambition At whose expense? Co-operation in manufacturing, margin of profit too small Reluctance of labour to face losses

(iii) *The Minimum Wage* *By* J RAMSAY MACDONALD, *M P*

(iv) *Copartnership in Industry* *By* C R FAY, *M A*

Profit-sharing is still a very rare thing in the aggregate of all business Full details of existing schemes in the United Kingdom will be contained in the forthcoming Report by the Board of Trade Profit-sharing is distinguished from gain-sharing by the fact that the latter is a premium on efficiency, payable irrespective of the general financial results of the year But it is less easy to distinguish profit-sharing from copartnership Two types of schemes are examined which claim this distinctive title -

I The Copartnership Trust in Lever Brothers, Limited, soap-makers, of Port Sunlight, Cheshire, instituted in 1909 —The main features of the scheme are as follows Partnership certificates are issued to qualified workers who sign the copartnership agreement These certificates entitle the holders to share in profits over 5 per cent *pari passu* with the holders of the ordinary shares, and the dividends, which are paid into savings-bank account to individual copartners, are freely withdrawable The certificates have no market value, and the scale of annual issue (at present 10 per cent on salaries and wages) is determined by the majority shareholder The allocation of certificates is left to trustees (the directors), assisted by an advisory committee of workers On retirement, partnership certificates are exchanged on certain terms for preferential certificates limited to 5 per cent interest, which lapse at death Workers who voluntarily leave the business or break their copartnership agreement forfeit all rights in the scrip In considering the possibility of imitation, regard must be had to the following points —

(1) That the firm is an exceptionally successful one, (2) that it is the maker of a proprietary article, (3) that it has previously conferred other benefits on its employees Figures for 1911 Certificates issued and outstanding—A Partnership, 275,429*l* , B preferential, 23,302*l* (nominal value), dividend on A , at 10 per cent , 27,543*l* , on B , at 5 per cent , 1,165*l*

II Copartnership in the Gas Industry, with special reference to the South Metropolitan Company —Copartnership began here in 1889 but since 1907 there has been rapid expansion, so that there are now thirty-six companies practising profit-sharing or copartnership, total capital, 50,000,000*l* , total of employees affected, 22,000 The financial side of the South Metropolitan scheme is based on a sliding-scale For every 1*d* reduction in the price of gas shareholders get a further 2*s* 8*d* per cent of dividend, and copartners a bonus of ¾ per cent Officers and workers are included in the scheme The present bonus is 8¼ per cent , and the stock held by employees over 300,000*l* The bonus, which is the absolute property of the copartner, is not paid in cash but reserved, half for savings-account, withdrawable in special circumstances, and half for investment in the company's stock Similar provisions appear in the schemes of other gas companies, with minor modifications

The advantages of the scheme are (1) the addition to wages, (2) the pro

motion of thrift, (3) the creation of good feeling and a sense of co-ownership. Sir George Livesey (late chairman of the South Metropolitan) claimed that the scheme paid the masters no less than the men, and had its influence in reducing the cost of labour and the price of gas. It is difficult, however, to establish exactly this causal connection. The gas industry is peculiar, having a partial monopoly of supply and a steady demand. Also its stocks are, in general, not speculative.

In certain cases these schemes have been opposed by the trade-unions. Copartnership makes strikes improbable and (while the copartnership agreement, current for three or six months, lasts) punishable under the Conspiracy and Property Act of 1875. But the agreements give security to the men also. The most powerful ties of copartnership are to be found in the democratic machinery by which the scheme is worked. A Copartnership Committee (composed of the chairman of the board of directors and twenty-six representatives of the board and twenty seven representatives of the copartners) manages the scheme and does other valuable work connected with accidents, superannuation, and insurance. Finally, the scheme safeguards the interests of consumers, who are peculiarly benefited when they are drawn from a working-class district.

Municipalities are liable to labour trouble, but copartnership would be difficult to apply here, owing to the special nature of municipal finance. The Stafford Corporation (gas and electricity departments) practises gain-sharing only. Copartnership, like syndicalism, emphasises the necessity of a closer connection between the worker and his work. But it is doubtful if special legislation, favouring copartnership, would be of any value to the movement.

(x) *Conciliation.* *By* Sir CHARLES W. MACARA.

The nature of the Inquiry of the Industrial Council is explained in the following 'terms of reference':—

(1) What is the best method of securing the due fulfilment of industrial agreements?

(2) How far, and in what manner, industrial agreements which are made between representative bodies of employers and workmen, should be enforced throughout a particular trade or district.

Already two days per week for eight weeks have been devoted to this Inquiry, but as there is still a large number of the representatives of prominent industries desirous of giving evidence, it was necessary to adjourn the sittings until the middle of October next.

Had the Inquiry been completed, and the Report presented to Parliament, I should have felt at liberty to deal with the subject, which will be discussed at your meeting, in a way that, under present circumstances, it is not possible for me to do. I may say, however, that the Inquiry, so far, has conclusively proved:—

(1) That when perfect organisation on both sides exists, even though disputes may occur they are usually settled without a stoppage of work.

(2) That the recent industrial unrest originated with trades not well organised, and that the disputes in those trades encouraged unrest among some of the well organised.

Having had twenty years experience in the cotton industry, I have a firm belief in making organisation on both sides as complete as possible, and I have seized every opportunity of bringing home to the workers the necessity not only for harmonious relationships existing between Capital and Labour, but of co-operating with the employers in grappling with the problems that confront the industries. The solution of these problems is vital to the maintenance of the industries, and equally concerns the welfare of Capital and Labour.

In these directions, in my opinion, lie the removal of industrial unrest, and the consequent successful carrying on of the industries of the country.

As indicating what is done in the cotton industry in the exchange of views between employers and workers on matters of vital importance to the industry, I may say that all the reports issued by the International Federation of Master

Cotton Spinners' and Manufacturers' Associations are sent to the leaders of the cotton operatives, and that, in return, the reports of the International Federation of Operatives' Trades Unions are sent to the heads of the employers' organisations

Both industrial and international peace are absolutely essential to the continued prosperity of a country like England, which, more than any other country, is dependent upon foreign trade for so large a proportion of the employment of the population

I have great hopes that ultimately an Industrial Federation will be formed in England on the lines of the great industrial organisation which already exists in Germany, and which practically embraces all the industries in that country There is no doubt that that body exercises a powerful influence in shaping prospective legislation affecting industry

MONDAY, SEPTEMBER 9

The following Papers were read —

1 *Land Banks* *By* ALLAN McNEIL

The feasibility of the establishment of Land Banks on a practical and an economic basis has been discussed intermittently for many years The present depressed state of agriculture and the recent report of the Departmental Committee appointed by the Board of Agriculture and Fisheries to inquire into the position of tenant-farmers on the occasion of any change in the ownership of their holdings, directed attention to the question Institutions formed for the sole purpose of financially assisting farmers in the purchase of their holdings and developing their industry have been established with marked success in other countries Some solution of the present difficult question as to the future of agriculture in this country is surely possible It may be that the prevalent feeling of unrest and uncertainty is accentuated by the campaign against land and its owners On the one hand we find that owners of large estates are selling—in many cases at considerable loss—their properties, while on the other hand the farmers view with disfavour the idea of being tenants of either the Government or County Councils

It is submitted that a scheme could be devised which would enable farmers to purchase their holdings when offered for sale, without increasing the annual payments which they now make to their landlords in name of rent, and which would at the same time return a reasonable rate of interest on the money advanced, provide a sinking fund for the redemption of the loan, and pay the working expenses of the institution

The system of Land Banks proposed is self-supporting and free from State control At first the institution would be confined in its operation to assist farmers in the purchase of their holdings, with the ultimate intention of extending its scope as the medium for the buying of seeds and manure, the purchase of pedigree stock, and the selling of farm produce

The necessary capital to enable the bank to begin operations would be placed by the State at the disposal of the managers of the institution Interest would be paid to the Government at 3 per cent on the amount of capital advanced and outstanding from time to time The Government get money from the Post Office Savings Bank depositors at 2½ per cent Further sums required would be obtained from the public by the issue of bonds, which bonds would be guaranteed, both as to principal and interest, by the State There should be no difficulty in getting as much money as is required At present when a depositor in a savings bank has at his credit the maximum limit, that money is, with his consent, used to purchase Consols, and the depositor thereafter has to take the risks of the market fluctuation of that stock It is proposed to authorise the savings-banks to issue transferable deposit receipts for multiples of 25*l.* on behalf of the Land Banks, guaranteed by the State, repayable in ten, fifteen, and twenty years at a graduated rate of interest from 2¾ to 3¼ per cent.

Money would only be advanced to the tenant of a farm who had been on his holding for five years prior to the date of sale. The price would be fixed,

failing agreement, by arbitration The purchase money would be advanced at such a rate of interest as would enable the farmer to continue to pay annually a sum equal to the amount of his rent The payment so to be received would include the interest paid by the bank for the money advanced, a sum towards a sinking fund, and a percentage to meet expenses and cover losses

The bank would hold the property in security until the debt was paid Any profit made would go to form a reserve fund No dividends would be paid

---

2 *A Comparison of British and German Insurance Legislation*
By Miss A Ashley

Germany was the pioneer of legislation to provide for the contingencies of industrial life

Britain was largely influenced by German example in the objects aimed at, but in part adopted different methods There was a difference of principle in the method of providing for old age, difference of principle, but practical approximation in method of providing for accidents, substantial similarity of the provision for sickness, with large divergencies, *e g*,

(*a*) Different treatment of invalidity
(*b*) Greater uniformity of obligations and benefits
(*c*) Larger scope for individual action

Difference in German and British atmosphere—question of malingering Britain's new departure, without precedent, in the direction of compulsory insurance against unemployment

3 *The Results of the Reformatory Treatment of Inebriates*
By David Heron, *M A*, *D Sc*

The present system of reformatory treatment of inebriates was initiated in 1899 Up to the end of 1909, 3,309 inebriates had been admitted and 2,293 discharged It is not unreasonable, then, to ask for some account of the results of reformatory treatment so far as the reform of the inebriates is concerned.

The following table gives the results of reformatory treatment of inebriates from all the available official sources —

Summary of Results of Reformatory Treatment of Inebriates.

Authority	No discharged	Doing well	Reformed	Much improved	Improved	Not relapsed	Not convicted
Parker, Brentry	227	75	—	—	—	—	—
Parr (Section I cases only)	133	—	59	—	—	—	—
Dunning, Liverpool	60	—	—	—	—	22	—
Atkinson, Leeds	28	8	—	—	—	—	—
Halketh, Hull	23	1	—	—	—	4	—
Wright, Newcastle	50	4	—	—	—	—	—
Nelson, London	74	—	—	—	—	—	33*
Baggallay, London	80	—	—	—	—	—	42*
Barradaile, Birmingham	21	—	—	—	—	—	8*
After-Care Association	407	82	—	—	—	—	—
Gomme, Farmfield	394	56	—	—	—	—	—
Gill, Langho	227	34	—	17	15	—	—
Dunlop, Scotland	181	12	—	—	—	—	—
Totals	1,905	272	59	17	15	26	83*

* Not convicted, after discharge, at the same police court.

Thus out of 1,905 after-histories of inebriates, 272 are said to be doing well for a limited period after discharge, 59 are said to have 'reformed,' though some of those were convicted of drunkenness after discharge from a reformatory, 17 are said to be 'much improved,' 15 were 'improved,' 26 'did not relapse,' and 83 were not convicted, after discharge, at the same police court

---

4 *Regional and Civic Surveys the needed Co-operation of the Sciences towards the Town Planning Movement* *By* Professor P GEDDES.

TUESDAY, SEPTEMBER 10

The following Papers were read —

1 *The Origin and Growth of the Jute Trade in Dundee and Germany* *By* JAMES CUNNINGHAM, *M A*

This paper attempted to give some account of the conditions which favoured the introduction of jute manufacture into Dundee and district, and of its subsequent development, which has resulted in the creation of a virtual monopoly for Dundee in the jute industry of the United Kingdom From the beginning of the eighteenth century the manufacture of linen goods was one of the chief industries of the Eastern Counties of Scotland Among these the coarser forms of linen used for sugar and cotton bagging were largely made in Dundee from the year 1747 onwards In the beginning of the nineteenth century the amount of these goods woven in Dundee for exportation was over twelve million yards The way was then prepared for the treatment of the new fibre jute, which was introduced in the second quarter of the nineteenth century The development of the new industry was rapid, first in regard to the amount manufactured, and secondly, of recent years, in the variety of the articles produced Dundee and its neighbourhood now consume nearly all the jute imported into the United Kingdom

The development of the jute industry in Germany followed somewhat the same lines at a later date It also arose out of a previous flax industry During the Crimean War, and indirectly as a result of that war, the attention of German flax-spinners was called to jute In the year 1861 the first jute mill in Germany was started The industry, especially since the introduction of protective duties in 1880, has flourished exceedingly, so that at the present date it rivals that of Dundee itself There is one striking difference to be noted between its development in this country and in Germany—viz , that, whereas in the former, as has been stated, the industry is almost wholly confined to one district, in the latter it is distributed over a wide area in the north of Germany

In conclusion, figures were given showing the present extent of the jute industry throughout the world These figures are probably only approximately exact

2 *The Economic Aspect of Scottish Water-Power* *By* A NEWLANDS, *M Inst C E*

The economic waste represented by the non-utilisation of the water power possibilities of the Scottish Highlands is at last beginning to receive the somewhat belated attention of our industrial life

Several causes have helped to bring this about The progressive policy in regard to hydro-electric power development all over the world has stimulated interest in our own possibilities, and the example set by the British Aluminium Co at Foyers and Kinlochleven has also served to point the way, but there are other indications which point to an industrial development in our country districts as being the solution of the present unrest which so markedly characterises our industrial life, and indeed threatens its well-being

What are the causes of this unrest? The great centres of industry are too congested and expensive for the workers; their housing conditions are unsatisfactory, the privacy of home life almost impossible, the expense and distractions of town life, as well as high rents and taxes, are a burden on them.

Employers are faced with the irritating restrictions of trade-unions, liability for accidents, insurance of workmen, restraint of Government supervision, and a growing taxation, all of which represent increased on-cost charges, and these, with a rising wages bill, are a heavy tax on production

The pressure and expansion of industrial progress now demand the severest economies in every phase of industry, as evidenced by the extended application of power to supersede manual labour and by the conservation of the commercial value of by-products hitherto considered as beneath notice In the matter of power—the mainspring of all industry—inventors vie with each other in the pursuit of economies.

Coal, with the advent of the steam engine, meant cheap power, and the presence of coal and iron ore and shipping facilities in certain localities largely explains the origin and location of our great industrial centres to-day

Probably coal must ever be our greatest source of energy, but the increasing cost of it demands economy in its use, and hence the attention being given to other sources of power Our water-power possibilities are as yet undeveloped, and by means of high tension electrical transmission hydro-electric energy can now be sold in favourable localities at probably about one half the expense of power from coal

It is manifest therefore that where cheap hydro electric power can be generated, where raw material can be got or can be imported—as much of it now is—where sea and rail facilities are available, where labour can be got or can be attracted by reason of healthy and economical conditions of living, industrial development is eminently practicable, and nowhere in Great Britain do these conditions exist to such a marked extent as on the seaboard of the Highlands of Scotland

This locality has hydro electric possibilities estimated at a million horse power, it has an indented and sheltered coast line for shipping and ample rail and road facilities, an equable climate, and a healthy, sturdy population unfortunately being attracted overseas by our competitors there

The Government policy of afforestation should be associated with that of water power development The funds in the hands of the Development Commissioners might also be made available in this direction, and, with the secondary possibilities of the land, the necessary stimulus would be provided for an industrial awakening in the Highlands of Scotland, for which, both by natural and by geographical location, they are so eminently adapted

3 *Dumping as it affects the Steel and Tin Plate Industries of South Wales By* J H JONES

4 *Do Trade Unions raise Wages on the Whole? By* A A MITCHELL

Trade unions aim not at increasing the total product, but at obtaining a larger share for labour at the expense of other factors of production For the purpose of this paper that is assumed to be a good thing Whether the total sum paid in wages will be greater under free competition or under combination enforced by strikes has been described by Professor Ashley as one of the open questions of economics

The trade-union argument takes various forms (*a*) It is argued that combination is necessary to put the workman on an equal footing in bargaining But (1) the question is whether combination is in fact a help or a hindrance. (2) The inequality is denied. In a trial of endurance, no doubt, the employer may be able to hold out longer by converting his capital into a fund for his own subsistence, but in employing it as capital he is as dependent on his workmen as they on him The alleged inequality therefore exists only in a régime of strikes and

lock-outs. (3) If both parties are combined, their relative strengths will not be altered.

(b) It is argued that under competition there is no downward limit to wages, save the least that will keep the workman and his family in life But (1) this is untrue historically. Wage rates have differed and do differ enormously, and on the whole tend enormously upwards (2) In the form of Ricardo's iron law the argument depends on an assumption as to population, and applies equally under combination (3) Apart from an indefinite increase of population, wages seem no more to tend to a minimum than to a maximum Competition of employers as much keeps them up as competition of workmen keeps them down.

(c) In particular it is argued that the subsistence level of the lowest workman fixed the wage rate This is fundamentally untrue The economically strongest workman required fixes the rate for the rest

(d) It is argued that it is possible to raise wages to a conventional standard of living above the *de facto* scale of subsistence This is a travesty of Ricardo

(e) It is argued that trade unions may raise wages as capitalistic combinations raise prices But (1) is there any reason to suppose that capitalistic combinations benefit capitalists as a whole? The Steel Trust gains at the expense of steel users (2) The necessity for combination arises where there is an on-cost Thus, without combination it might pay railways to compete for any additional traffic that would pay the charges incidental to itself and contribute anything, however little, to fixed charges But labour has no on-cost (3) Capitalistic combinations can control the output Trade unions cannot limit the supply of men.

The true analogue of labour is a given quantity of perishable goods, and it is submitted that there is no way in which such can be disposed of for so large a total price as by competition of both buyers and sellers Any attempt to exact more than a competitive price necessarily means that some remain unsold In the sphere of labour, the demand—i e , the capital—is taken to some other country, and the unemployed workmen, besides the injury to themselves, are a standing menace, as potential blacklegs, to the rest

It is argued that it may be more profitable to support some men in idleness than to lower the rate by suffering their competition, but, e g , would the home producer ever apply that argument to his foreign competitor?

Nor is it an answer to say that a transference from profits to wages will increase spending power and so stimulate trade

It is argued that lessened profits promote economy and efficiency of management (and in particular the introduction of machinery) This is just the old argument that low wages make men work harder, and is not very consistent with the modern argument that high wages promote efficiency

By lessening the demand for labour trade unionism (a) lessens employment, (b) produces sweating, (c) in addition to general, intensifies periodic, or cyclical, unemployment The proper remedy for lessened demand is, as in the sale of stocks or commodities, an all-round diminution of price, not a suspension of transactions Other evils are (d) restriction of output, (e) limitation of apprentices, (f) opposition to labour co-partnership or any scheme, however beneficent, which is believed to impair the efficiency of the strike weapon; (g) opposition to ameliorative or regenerative work, of charitable agencies or in prisons, in which, from the nature of the case, the standard wage cannot be given, (h) the development of the ideal, according to which labour contracts are adjusted between a joint board of employers and a union, and the idea of the general strike mean (1) that good employers are no better off than bad, (2) that the whole of an industry may be paralysed because a single workman is alleged to belong to the wrong union

---

5 *The Nationalisation of the Western Railroad* By M Yves Guyot

Was the purchase by the State of the West of France railroad caused by a desire to reduce expenditure and to improve the means of transit? No; but following the elections of 1906, M Clemenceau, then Prime Minister, felt a desire to give some satisfaction to the Socialist and Radical-Socialist parties by 'socialising' something In November he handed in a proposal for the purchase of the Western line What was the argument put forth in favour of State ownership?

That the company would never be able to repay the sums which had been advanced to guarantee the interest On December 31, 1905, the indebtedness of the Western line amounted, in moneys due to the State, to 302,569,000 francs, and in interest to 117,300,000 francs, in all a total of 419,880,000 francs, but the Western Railroad possessed rolling-stock estimated at 351 millions Subjecting it to a reduction of 30 per cent, the price to be paid would therefore have been 245 million francs That difference of 174 millions was the great argument put forward by the redemptionists to hasten the purchase

How could redemption protect those interests?

The guarantee of interest to shareholders amounted annually to 11,550,000 francs, and was to come to an end in 1935, it was prorogated till 1951, and afterwards until 1956, reduced to 6,300,000 francs The remaining sums due by the company were written down as being 7,122,000 francs, and not 174 millions

The results of the management by the State were increased expenditure the deficiency of the Western Railroad was, in 1908, 28,522,000 francs, that of the State, in 1912, was 83,675,000 francs, the increase of working expenses amounts to 72,304,000 francs, out of which the staff draws 52,296,000 francs According to M Pierre Baudin's report to the Senate, on a total of 67,967 persons employed, 36,816, or 54 per cent, were told off on sick leave, and it was necessary to increase the workers by 7,440 units While working expenses from 1908 to 1912 have increased by 72,304,000 francs, the gross receipts have risen from 217,645,000 to 244,335,000 francs, the increase only representing 26,689,000 francs

The effect on State credit the Minister of Finances issued this year four per cent bonds At once the three per cent fell to 93 65, and afterwards to 91 95

The redemption of the West of France Railroad was a complete failure

Section G.—ENGINEERING.

President of the Section.—Professor Archibald Barr, D.Sc., M.Inst.C.E.

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

One of the great engineers of the past, Leonardo da Vinci, prefaced a collection of observations on various themes, including the Mechanical Arts, with the remark: 'Seeing that I cannot choose any subject of great utility or pleasure, because my predecessors have already taken as their own all useful and necessary themes, I will do like one who, because of his poverty, is the last to arrive at the fair, and not being able otherwise to provide himself, chooses all the things that others have already looked over and not taken, but refused as being of little value. With these despised and rejected wares—the leavings of many buyers—I will load my modest pack and therewith take my course.' These words describe, with some approach to exactitude, the position in which I find myself, and may form a fitting introduction to an Address that will be discursive rather than systematic, and perhaps more critical than constructive.

It may be less true to-day, than it was four hundred years ago, to say that all important matters concerning the existing state of the mechanical arts have been dealt with in spoken or written addresses. Each year there might be found sufficient subject-matter for a general survey of the ground that has been covered or a sketch of what lies before us. But each important advance is nowadays recorded as soon as it is made, and I do not feel that I have any special call to assume the rôle of the historian, nor can I claim any right to don the mantle of the prophet.

A President of this Section, who is not disposed to deal with the general aspects of the progress being made in the department of science allotted to us, can usually find a large enough subject for his Address within the limits of that part of our wide field with which his own work has been more particularly identified, and it might be expected that I would devote my Address to a discussion of the conclusions at which I have arrived during thirty-six years of practice and experience in the teaching of mechanical science. But so much has been said of late on the training of engineers, and so many divergent and even irreconcilable opinions have been expressed regarding the lines such training should follow, that I feel sure I shall be relieving the apprehensions of some of my audience if I begin by stating that I do not propose to inflict upon you a discourse on that threadbare theme. There are limits to the endurance even of those who practise a profession well calculated to inculcate the virtues of patience and forbearance.

When we have as President of the Section one who has broken new paths in the exploration of the territory assigned to us, or to whose labours the fruitfulness of some corner of the domain may be chiefly attributed, we would hardly be disposed to tolerate the omission from his Address of an account of his own

special work, in investigation or in practice, and the developments to which it is leading But while, no doubt, every worker is the chief authority on something or other, the plot he cultivates may be so restricted in area, and its products may bulk so little in the general harvest, as to form no suitable topic to engage the attention of his fellow-workers on such an occasion as this.

When an engineer leaves practice in the great, and takes to the devising and production of what are usually referred to specifically as 'scientific instruments' (though all machines and mechanical appliances may properly be classed as such), his colleagues in the profession may be disposed to look upon the change as a degeneration of species Naturally I am not disposed to accept such a verdict Remembering the careers of those who did most in the founding of the various branches of present-day practice, I am quite prepared to accept as applicable another phase borrowed from the language of the biologist, and to let it be called a 'reversion to a more primitive type' But instead of dealing with the narrow branch of applied science with which my own practice is chiefly connected, I prefer to utilise the short time at my disposal to make some observations upon a larger and more general theme The thesis which I propose to uphold may not fall very obviously within the scope of the original aims of the British Association, but it has, at least, an intimate bearing on the work of those who are concerned with the applications of mechanical science

Tredgold's oft-quoted definition of engineering as 'the art of directing the great sources of power in nature for the use and convenience of man' may well be taken, and often has been taken, as a text upon which to hang a discourse on the importance of the profession to which many of us belong, the leading part it has played in the process of civilisation, and the dependence of the world to-day on its activities But the words suggest failures as well as achievements, and responsibilities no less than privileges The definition suggests that the engineer not only fails in his vocation if he does not accomplish something for the use and convenience of man, but, further, that he acts contrary to the spirit of his profession if he directs the sources of power in Nature to the unuse[1] or inconvenience of man, and surely we must understand by 'man' not the engineer's immediate client but mankind in general The works of the engineer are to be used by some people, they have to be endured by all

Taking the highest view of our calling--and surely we do not hold that ours is in any sense a sordid or selfish vocation—the engineer fails in the fulfilment of his duty in so far as his works are detrimental to the health or destructive to the property of the community, or in so far as they are unnecessarily offensive to any of the senses of those who are compelled to live with them There has been too great a neglect of such considerations The medical practitioner is held to be negligent of his duty if he acts solely in the immediate interests of his patient, and does not take due precaution to guard against the spread of disease or the offence of the community by the exhibition of unsightly forms We should take as high a view of our responsibilities

In his Presidential Address to the Association last year Sir Wm Ramsay said that the question for the engineer has come to be not 'can it be done?' but 'will it pay to do it?' The answer to this question, in respect to any particular proposal, depends on the width of view we take in answering two preliminary questions whose interests are we to consider? and, what do we mean by paying? Of course, there are limits that must be set in answering each of these; my present contention is that these limits are usually much too narrowly drawn A road surveyor may save a few pence or shillings to his county council by leaving a piece of newly metalled road unrolled --because the clock strikes the hour for retiring—and may thereby cause expense, amounting to pounds, it may be to hundreds of pounds, through damage to motor-cars or the laming of horses (not to speak of loss of life or limb), to the users of the road, who are, after all, the clientèle he is there to serve Does it pay? The authorities of a city will spend large sums on the adornment of the streets with stately and ornate buildings, and on the purchase of works of art—and rightly so, though comparatively few of the citizens can appreciate or even give themselves the chance

[1] We have no word to denote very clearly the negative of *use*, as the term is here applied, *unuse* may serve for the present

of appreciating them—while they will tolerate or even be directly responsible for the running on these same streets of quite unnecessarily ugly and noisy tramcars, and congratulate themselves on the drawing of a paltry income from the display of hideous advertisements that are constantly before the eyes of the whole community Does it pay thus to separate æsthetic from utilitarian demands and interests?

It is too much to assume that engineers could meet all the reasonable demands of their immediate clients without producing, at least temporarily, secondary effects that may be of inconvenience to some members of the community. Bacon, indeed, said that 'The introduction of new Inventions seemeth to be the very chief of all human actions Inventions make all men happy without either Injury or Damage to any one single Person,' but Bacon was a philosopher, and dealt with ideals rather than with hard facts, and in his times inventors had not yet begun to dominate all the elements of our physical environment Had he lived to-day beside one of our country roads he might have had something to say, in another key, regarding motor-cars and dust; or had his lot been cast in the proximity of a great centre of industry he might have modified his conviction of the universality of the benefits conferred by the inventor He might even have been disposed to agree with a literary man of to-day who is reported as asserting that 'The universal and blatant intrusion of Science into our lives has resulted in a total disappearance of repose' Isolated and unqualified statements such as those I have quoted are like proverbs—you can always find two that are directly opposed The truth lies about midway between these extremes, or rather there are aspects of the facts in regard to which one is an approach to the truth, and aspects in which the other has some justification Our aim should be to make Bacon's dictum have more of truth and Mr Stephen Coleridge's assertion have less foundation in fact And the outlook seems to me to be a very hopeful one, though to be able to take an altogether favourable view of the tendencies of the present time, one must be an optimist of the true order—'One who can scent the harvest while the snow is on the ground'

When we examine into the immediate causes of the injuries and inconveniences that result from our activities we find that they are due in all, or almost all, cases to failures rather than to successes The more completely the engineer achieves the primary end of his work the less is the damage or injury that can be laid to his charge If it can be shown that this is a very general law, as I think it can be, we may look forward to the elimination, as a direct result of progress in the mechanical arts, of the nuisances and inconveniences for which, in some measure at least, we must accept responsibility And not only so, but the converse will be equally true—the more we keep in view the removal or avoidance of anything that can cause offence, the more rapidly we shall advance in the attainment of the primary ends at which we aim Consider, by way of example, the nuisance to which I have referred, and of which we hear so much—the raising of dust by motor-cars I shall not discuss the debated question as to how far the motor-car produces dust, or only distributes it, nor shall I deal in detail with the possible remedies We hope to have a paper on the subject at this meeting from one of our leading authorities. For my present purpose it suffices to point out that it is no part of the function of a road surface to fritter itself down into dust under traffic of any kind The ideal road would be one that would not wear at all, and the nearer we approach this ideal of a permanent road surface, the less will be the inconvenience caused, not only to those responsible for the upkeep of the road, but to the general public And conversely, the more attention we give to the devising of a dustless road the more rapid will be our advance towards the provision of one best suited for all the purposes which a road is intended to serve We had dusty roads before the motor-car came into being, but the demand that is being forced upon the engineer to eliminate this nuisance is leading to an improvement of our roads for all users The inventors of the automobile will yet merit the thanks even of those who, bemoaning the blatant intrusion of science into our lives, may discard the railway train and the motor-car and take to the stage-coach of their grandfathers with a view to the recovery of some of the lost repose

Again, the combustion of fuel does little harm to anyone, it is the imperfection of the combustion that is the main cause, almost the sole cause, of injury to health, to property, and to the amenity of populous centres Of course

one knows that smokeless combustion is not necessarily, nor always, the most economical, but that is only because we have not yet learned how to use fuel in anything like a perfect manner. But all the tendencies at the present time are towards improvement, and the more attention we pay to the elimination of the smoke nuisance the more rapid will be our progress in the economical use of one of the most valuable of our inheritances. It is therefore clearly the duty of every engineer who has to do with power or heat production—for the credit of his profession and even in the interests of his immediate clients—to consider the use and convenience of all who can be affected by the work for which he is responsible. The time is not far distant when the direct burning of bituminous coal in open grates will be looked upon as not only a source of serious harm but as a culpably wasteful practice. Great progress has been made in processes for the partial distillation of coal by which a free burning and quite smokeless fuel is prepared and valuable by-products (so-called) are conserved. If all engineers concerned with the design and application of plants in which coal is used had a due sense of their responsibilities to the community, progress would have been, and would to-day be, much more rapid, and economies would be effected that would, in themselves, amply justify the application of more scientific methods of utilising the constituents of a very complex material, which we are too apt to look upon as merely a convenient source of heat—plentiful enough and cheap enough, as yet, to be used in a most wasteful manner. It will not be to the credit of our profession if it should require restrictive legislation not only to prevent a gross interference with the health and comfort of the community and the amenities of our centres of industry or of population, but to effect economies in the utilisation of the chief of the sources of power which it is our function to direct to the best advantage of all concerned.

In other directions also we see that progress towards economy is leading to a reduction, and possibly to the entire elimination, of all the nuisances associated with the older methods of power and heat production. The great improvements that have recently been made in producer plants and gas engines have rendered out of date, as regards economy, at least the smaller sizes of steam plants which are so fruitful a source of injury and inconvenience to the community, and we now have engines of the Diesel, and the so-called semi-Diesel, types that can utilise natural oils, and oils obtained in the distillation or partial distillation of coal, not only with an efficiency hitherto unattained in heat-engines, but 'without injury or damage to any one single person'—except possibly the maker of inferior [2] plants.

Present indications point to the coming of a time, in the near future, when the power and heat required for industrial and domestic purposes will be distributed electrically, in a perfectly inoffensive manner, from large central stations, and even at these stations there will be no pollution of the atmosphere that could give the most sensitive of critics any just grounds of complaint against the intrusion of science into our lives. In his Presidential Address to the Institution of Electrical Engineers in November 1910, Mr Ferranti dealt in a most masterly way with this, which is undoubtedly the greatest of the many schemes at present before the engineering profession. That address reads like a chapter from a romance of Utopia, but unlike most of the forecasts that have been presented to us of ideal conditions in a world of the future, the system which Mr Ferranti sketches out, and advocates with so much knowledge and convincing argument, does not depend for its reasonableness on the postulation of a perfected humanity. It would not only provide vastly improved conditions of life for the community as a whole, but it would satisfy the more selfish aims of the users of power and the makers of machinery, by increasing the economy of production and stimulating the demand for mechanical appliances. No doubt there may be some who will hold that to commend any worthy scheme, to those who might carry it out, by an appeal to their selfish interests is an altogether immoral kind of argument. I do not think so. Advancement of the race through

[2] My typist in transcribing a rather illegible draft of this passage substituted for the adjective I have here used the less restrained, but perhaps equally appropriate one, 'infernal,' but I noticed this in time to amend the emendation. I had no intention to speak so candidly of any of the works of members of my own profession.

benefits to the individual is, at least, not inconsistent with nature's method of securing progress. However much we may desire to develop a purely altruistic spirit in men of all classes we must meantime make the best of human nature as it is, and recognise that the rapidity of our progress toward better conditions of life will be in proportion to the advantages that each advance can promise to those who would be immediately concerned in its realisation

It is just a hundred years since passengers were first carried on the Clyde in a mechanically propelled ship, and to-day—when they are not too completely obscured by smoke—we can see the successors of the 'Comet' plying on that river with power plants of greatly superior overall efficiency but showing little advance in regard to the combustion of the fuel Had the emission of smoke from river craft been prohibited years ago, there is little doubt that engineers would have let few days pass without arriving at some solution of the problem of inoffensive power production, and the demand for economy would have looked after itself How much better it would be were engineers to take the wider view of their duties and responsibilities to which I have referred, and realise that they are acting contrary to the true spirit of their profession when they produce appliances that pollute the atmosphere for miles around to the hurt and inconvenience of those whose 'use' they are intended to serve But this year a ship has left the Clyde that we hope may be the forerunner of a new race which will attain a higher efficiency than any of the direct descendants of the 'Comet,' and that will ply their trade without inconvenience to man or beast, who can claim some right to be permitted to enjoy an unpolluted atmosphere and the measure of sunshine which Nature—sparingly enough in those regions—intended to provide.

But there are injuries which we may inflict upon the community other than those to health and physical comfort Every one, even the least cultured, has some sense of the beautiful and the comely, and is affected by the aspects of his environment more than he himself can realise The engineer, then, whose works needlessly offend even the most fastidious taste is acting contrary to the spirit of his profession, at its best There has been far too great a disregard of æsthetic considerations in the everyday work of the engineer—we usually take a too exclusively utilitarian view of our calling We should not be prepared to accept, as referring to the arts we practise at their best, the distinction drawn by a philosophical writer between 'the *mechanical* arts, which can be efficiently exercised by mere trained habit, rote, or calculation,' and 'the fine arts, which have to be exercised by a higher order of powers'[3] And I think it can be shown that a greater regard for artistic merit in our designs would not necessarily lead to extravagance, but, in many cases, would conduce to economy and efficiency It is at least true—and much less than the whole truth—that greater artistic merit than is commonly found in our works could be attained with no sacrifice of structural fitness, or of suitability for the purposes they are designed to serve

There was a time when engineers made desperate attempts to secure artistic effects by the embellishment (?) of their productions with features which they believed to be ornamental Fortunately the standard of taste has risen above and beyond this practice in the case of most members of our profession and most of our clients We are all familiar with illustrations of philosophical instruments, and other mechanical contrivances, of the early times, that vied in lavishness of adornment—though not in artistic merit—with those wonderful astronomical appliances that were carried—as trophies of war!—from Pekin to Sans Souci Many of us can remember a time when the practice had not altogether disappeared, even in the design of steam engines, lathes, and other products of the mechanical engineer's workshop I well remember in my apprenticeship days, the building of a beam engine that was a triumph of ingenuity in the misapplication of decorative features In place of the mildly ornamented pillars and entablature of Watt's design, there was provided, for the support of the journals of the beam, a pair of A frames constructed in the form of elaborately moulded Gothic arches flanked by lesser arches on each side, while the beam itself and many other parts were plentifully provided with even less

[3] *Ency Brit*, eleventh edition, article 'Art.'

appropriate embellishments, borrowed from the art of the stone-mason. It is some consolation to remember that the clients for whom the engine was built were not of this country, and that the design itself was not a product of the workshop that was favoured with the contract to produce this amazing piece of cast-iron architecture We have all seen wrought-iron bridges the inattractive features of which were concealed by cast-iron masks—in the form of panelling, or of sham pillars and arches with no visible means of support—that not only have no connection with the structural scheme, but suggest types of construction that could not, by any possibility, meet the requirements Structures of this kind remind one of the pudding which the White Knight (with good reason when we remember the characteristics of his genius) considered the cleverest of his many inventions It began, he explained, with blotting-paper, and when Alice ventured to express the opinion that that would not be very nice, he assured her that though it might not be very nice *alone* she had no idea what a difference it made mixing it with other things—such as gunpowder and sealing-wax

There are, and must always be, wide differences of opinion regarding what is good or bad in matters of taste, but we may go so far in generalisation as to say that we can admire the association of elements we *know* to be incongruous only in compositions that are intended to be humorous 'All human excellence has its basis in reason and propriety, and the mind, to be interested to any efficient purpose, must neither be distracted nor confused '[4] But to be able to judge of the propriety or reasonableness of any composition we must have some knowledge of the essential qualities and relationships of its component parts, and excellence cannot depend upon an appeal to ignorance We can quite imagine that the White Knight's pudding would appeal as an admirable and most ingenious concoction to one who lacked a knowledge of the dietetic value of blotting-paper and was willing to take for granted the excellence of gunpowder as a spice and of sealing-wax as a flavouring No artist would be bold enough to include a polar bear or a walrus in the composition of a picture of the African desert, nor be prepared to consider as a legitimate exercise of the artistic imagination the depicting an Arab and his camel wending their weary way across the Arctic snows He would recognise the incongruity, and might even realise that it is only a lack of imagination or of true inventive power that could lead anyone to resort to such measures for the securing of a desired colour scheme These are lengths to which even artists will not go in the arrangement of elements in a composition But an artist *will* secure a colour scheme at which he aims by the introduction into his landscape of a rainbow in an impossible position, or of impossible form or dimensions, or with colours arranged according to his own fancy, though in this there is a much more essential unreasonableness A polar bear might be transported to the desert, and an Arab might conceivably find his way to the regions of snow and ice, but a rainbow cannot wander from the place assigned to it by Nature, nor can it have other than the ordained form or dimensions or sequence of colours No artist would paint a figure holding a candle and make the light fall on the side of the face remote from the source, but he will, and usually does, paint the moon illuminated on the side remote from the sun Why? Simply because he has not before his mind the essential absurdity of the scheme, if indeed he knows why the moon shines Artists who deal with nature in any of its aspects, may be commended to 'mark, learn, and inwardly digest' Whistler's definition of their calling 'Nature contains the elements in colour and form of all pictures but the artist is born to pick and choose, and group with science, these elements, that the result may be beautiful' Whether or not we are to understand that Whistler intended to include an accurate knowledge of physical facts and phenomena in what he calls *science*, he cannot have meant anything less than *sense*

So in regard to the arts of construction, we may say that Mechanical Science provides the elements of all structures, and the craftsman—be he called engineer or architect—is born to pick and choose, and group with science, these elements, that the result may be useful—and not devoid of grace

The only valid excuse for such departures from the fit and rational in painting

[4] Mr Duppa's *Life of Michaelangelo.*

or in structural design, as those which I have instanced, is ignorance on the part of the designer of the nature of the elements he employs, or a lack of skill to devise a possible or reasonable arrangement of details that will secure the general effect he desires

It may almost savour of sacrilege to quote, in this connection, from the writings of that 'wild, wilful, fancy's child' the story of whose eight short years of life and literary work Dr John Brown has given in his charming 'Pet Marjorie'—a record of perhaps the shortest human life that has formed the subject of a biography. But the lines are too pertinent to my purpose to be withheld, and the frankness of the confessions they contain, of a childlike limitation of artistic power, may be commended to those who practise either the fine arts or the arts of construction, and feel compelled to 'trust to their imagination for their facts,' or to resort to the association of incompatible details for lack of knowledge, or of ability to attain their ends by more reasonable means

Marjorie writes of the death of James II —

'He was killed by a cannon splinter,
Quite in the middle of the Winter,
Perhaps it was not at that time,
But I could find no other rhyme!'

'Quite in the middle of the winter,' describes August 3, 1460 A D, with no wider licence than we find assumed in the works of more experienced, if less candid, artists and craftsmen Again in her sonnet to a monkey—written, we must remember, when she was six or seven years of age—she acknowledges the compelling power of an artistic aim —

'His nose's cast is of the Roman
He is a very pretty woman
I could not get a rhyme for Roman
So was obliged to call him woman'

It may seem that I have wandered widely from my text those who found discourses on texts usually do! But there is, or ought to be, a closer connection than is usually recognised between the work of the engineer and that of those to whom we usually restrict the title of artist There was no great gulf fixed between the fine arts and the utilitarian arts in earlier times Some at least of those to whom we owe the greatest advances in the fine arts were eminent also in the arts of construction We may claim such men as Michelangelo, Raphael, and Leonardo da Vinci as masters in the arts of construction as well as in those with which their names are usually associated The separation of the beautiful and the useful is quite a modern vice But much that I have ventured to say in the digression—if such it be—is applicable, with little or no alteration of terms, to the work of our own profession The architect or engineer who, for the sake of effect, fills the space between the flanges of a beam or girder with slabs of stone, or cast-iron pillars and arches, that could not fulfil the function of a web, exhibits just the same lack of skill as Pet Marjorie owns up to—shall I say?—like a *man* Such practices have no 'basis in reason and propriety,' and the employment of such 'decorative features' is certainly not a 'grouping of elements with science' It is said that 'The highest art is to conceal art', the lowest in matters pertaining to our profession is to conceal ill-devised construction with false and senseless masks But what I have said has, I think, a sufficiently obvious bearing on the mechanical arts—I need not further point the moral

There is an old maxim to the effect that 'the designer should ornament his construction and not construct his ornament' This is an admirable rule so far as it goes, but it should be subordinated to a higher rule, that he should ornament his structure only if he lacks the skill to make it beautiful in itself A structure of any kind that is intended to serve a useful end should have the beauty of appropriateness for the purpose it is to serve It should tell the truth, and nothing but the truth, and if its character be such that it can be permitted to tell the whole truth, so much the better It should be beautiful in the sense in which we commonly use the term with respect to a machine—we call a mechanical device beautiful only if it strikes us as accomplishing the end for

which it is designed in the simplest and most direct way. Our works—like the highest creations in nature—should be beautiful and not beautified. 'Beautified' should be considered a vile phrase when applied to a work of construction, no less than when used to characterise a fair Ophelia. Artists accept the human form, at its best, as the highest embodiment of grace and beauty, but there is not a curve in the figure that is not the contour of some structural detail that is there for a definite purpose. The practice of resorting to extraneous adornments to minimise crudities of structural scheme had its rise—if I mistake not—in the comparatively recent times when culture and taste were at their lowest. It is specially characteristic not only of earlier times, but of the earlier stages of the design of any particular product. It has already disappeared in some cases and will continue to disappear from the practice of the arts of construction as skill and taste develop. I have already alluded to the abandonment of ornament in the design of machines, and I think there can be no one, with any sense of the fit and pleasing, who does not approve this change in practice. The stage coach and horses of former times were lavishly decorated—the carriage of to-day is more graceful and pleasing in virtue of the simple elegance of its lines. In the best domestic architecture of to-day we see the same tendency to trust for effect, more and more, to an artistic grouping of the lines and masses of essential parts and the gradual abandonment of purely decorative features, without and within. There was a time when the hulls and riggings and sails of ships were lavishly ornamented; now even the figurehead—the last remnant of barbaric taste—has disappeared, and do we not find in a full-rigged ship of to-day (or yesterday, perhaps one should say) a grace and dignity that no extraneous embellishments would enhance? From the racing yacht the designer has been forced, by the demand for efficiency, to cast off every weight and the adornments that so beset the craft of earlier times, with the result that there is left only a beautifully modelled hull, plain masts, and broad sweeps of canvas, and we can hardly imagine any more beautiful or graceful product of the constructive arts. These examples will serve to illustrate the contention that the attainment of the highest efficiency brings with it the greatest artistic merit. But in the development of the yacht of to-day, through many stages, the designer has been forced, from time to time, to strive to combine grace with efficiency. Selection on the part of clients must have eliminated ungraceful forms when more beautiful ones could be found, and therefore the advance has been rapid. I think I may appeal to this illustration to support the further contention that advance in efficiency may be helped and not hindered by keeping in view an æsthetic as well as a utilitarian aim. Further illustrations will occur to anyone who has studied the development of design of structures or machines.

It is a matter of constant remark, and with justice, that steel bridges, as a class, are much less pleasing to the eye than those of stone. The reasons for the contrast in artistic merit are not far to seek. The building of stone bridges is an ancient art, and survival of the fittest and selection—even with little creative skill on the part of the designers—would have led to the development of types having, of necessity, at least the elegance of fitness. But, further, this art has come down through the times to which I have referred when artistic and utilitarian aims had not yet been divorced in the practice of the crafts; and, further still, the practice of building in stone has been in the hands of architects, as well as of engineers, and architects are expected to be artists, and are trained as such. On the other hand, construction in steel is a very modern art, and it has been in the hands of engineers, who usually neglect, if they do not despise, the study of the fine arts. But why have architects, with their artistic training, not succeeded in producing structures in steel as admirable as those they design in stone? Partly, no doubt, because they are hampered by tradition. They have not yet fully realised the difference in spirit that must characterise fit designs in the newer and the older materials. No one can be an artist in any material the possibilities and limitations of which he has not fully mastered. Again—if a common engineer may venture the criticism—the architect, as a rule, has not sufficiently mastered the *science* of construction, and has been too much addicted to taking the easy course of adopting a decorated treatment instead of striving to secure elegance of structural scheme as such; and decoration, at least on anything like traditional lines, is wholly incompatible with the best possibilities of steel as a structural material. Progress is being made in the art of

designing efficient and graceful structures in metal, but the best results can only be attained by a designer who has a thorough scientific and technical knowledge of the properties of steel and the processes of its manipulation on the one hand, and cultured artistic sense and capacity on the other These should not be considered as appropriate equipments for separate professions

There are many, however, who have a rooted conviction that structures in steel can never be so beautiful as those in stone This I believe to be altogether wrong It arises partly from the crudity of design that characterises most of the steel structures that have yet been erected, and partly from preconceived notions as to what is fitting in proportions and massiveness We can quite imagine that a native of the Congo region whose notions of the proportions suitable and comely for a quadruped were founded on his familiarity with the hippopotamus would, at first sight, consider the racehorse sadly lacking in substance and solidity, but, in time, he might come to recognise some measure of gracefulness in a creature that has been developed to meet requirements that hitherto he had not fully considered

Mr Wells has said in his 'New Utopia' 'The world still does not dream of the things that will be done with thought and steel when the engineer is sufficiently educated to be an artist, and the artistic intelligence has been quickened to the accomplishment of an engineer' But we need not postpone till the advent of a complete Utopia the full realisation of our duty to practise our profession as far as in us lies, with due regard for the material interests and the æsthetic susceptibilities of all who can be affected by the works for which we are responsible

The following Papers and Report were then read —

1 *The Ignition of Gaseous Mixtures by Momentary Electric Arcs* *By* Professor W M Thornton, *D Sc* , *D Eng*

The inverse of the gas-engine case—that is, under what conditions will single electric sparks fail to ignite gas—is of importance in coal-mining The present note is an investigation of the least currents, direct and alternating, which are required to ignite gaseous mixtures at different voltages and frequencies The lower and upper limits of mixture within which ignition is possible are found to be 4 25 and 14 per cent for fire-damp in air, 6 and 40 per cent for coal gas There is a well-defined maximum of sensitiveness to ignition at 7 per cent in the former, 8 5 per cent in the latter With direct voltage the least igniting current is approximately proportional to the reciprocal of the voltage, with alternating voltage the frequency is of more importance, and the current remains constant over a long range of voltage, being higher for methane than for coal gas The energy of spark which will just ignite the most sensitive mixtures is about 0 10 joule, corresponding to the combustion of 37 c c of an 11 per cent mixture of coal gas Single sparks therefore give relatively poor ignition

It would appear from the results that when alternating current is used for signalling or where there is no continuous sparking at a contact, the risk from electrical signalling in coal mines is extremely small Where there is sparking, as at a vibrating contact, the bells must be enclosed in flame-proof cases, or be situated in places which cannot be reached by fire-damp in mixtures approaching 4 per cent

2 *Fifth Report on Gaseous Explosions* —See Reports, p 192

3 *Description of the Home Office Experimental Station for Research on Explosions* *By* Professor H B Dixon, *F R S*

FRIDAY, SEPTEMBER 6

Joint Discussion with Section A on Wireless Telegraphy.—See p. 401

The following Papers were then read:—

1. *The Production of Electrical Oscillations by Spark-Gaps immersed in Running Liquids.*[1] *By* W. H. ECCLES, *D.Sc.*, *and* A. J. MAKOWER, *M.A.*

The most common method of generating electrical oscillations for the purposes of wireless telegraphy is by the discharge of a condenser through an inductance coil and air-gap in series. When a large amount of energy has to be handled there is a tendency for a permanent arc to form between the electrodes, and this reduces the efficiency of the apparatus. In the present paper is described a series of experiments designed to determine whether the efficiency can be increased by making the spark occur in a flowing liquid. The liquids employed in the experiments were water and transformer oil. Although the results show that the efficiency attained is only of the same order as that which can be attained by the air-spark, the details of the experiments are of interest and suggest methods that would be useful in certain contingencies.

The simplest form of discharger worked with consisted of an ebonite tube through the sides of which the electrodes protruded to form a small spark-gap in the middle of the bore. When water was passed down the tube, very steady oscillatory current could be obtained with voltages of about one thousand volts across the gap. When oil was used the voltages had to be of the same order as those employed with air-gaps in order to obtain the best results, and, at the same time, the gaps had to be smaller than air-gaps. Other forms of discharger were made which provided for the spark to take place under great hydrostatic pressures, but these showed no consistent electrical advantage over the dischargers operated with liquids at atmospheric pressure. In the paper damping curves are given for various degrees of coupling between the primary and secondary oscillatory circuits. These show that the water spark follows nearly the same laws as an air-spark, and that the spark in oil exhibits the phenomenon known as impact excitation. Dischargers of the type described possess the advantage over the open air-spark that their discharge can be made practically noiseless.

2. *The Impedance of Telephone Receivers as affected by the Motion of their Diaphragms.*[2] *By* Professor A. E. KENNELLY *and* G. W. PIERCE.

The authors made a research on the effect of frequency upon the electrical properties of various telephone-receivers, between the limits of 430 and 2,400 cycles per second. The Rayleigh modification of the Wheatstone bridge was used, and the measurements were conducted with constant voltage (0.3 to 1.0 volt in different series) at the telephone-receiver terminals.

It was found that the vibration of the telephone diaphragm materially affected the resistance and inductance of the receiver. Measurements were therefore made both with the diaphragm arrested, or *damped*, and with the diaphragm *free*. In the instruments tested, the 'damped resistance' was found to be a simple quadratic function of the frequency, and also to be in inverse ratio to the inductance, over a considerable range of frequency.

The 'damped impedance' of a telephone-receiver, when plotted with reactance ordinates and resistance abscissæ, increases when the frequency is increased, advancing regularly along a smooth curve. The 'free impedance,' however, moves around a closed loop, in that portion of the frequency range lying in the neighbourhood of the fundamental frequency of the diaphragm. There are thus

[1] See *The Electrician*, September 13, 1912. [2] *Ibid.*

two distinctly different frequencies at which the free impedance of a telephone is one and the same

If the 'damped impedance' of a receiver is subtracted vectorially from the 'free impedance,' the difference may be called the 'motional impedance' of the receiver at the frequency considered, because it is the change in impedance produced by the motion of the diaphragm It was discovered that the locus of the motional impedance of a receiver, as the frequency advances from 0 to 2,400 cycles per second, is a circle passing through the origin of co-ordinates In other words, if we plot the motional reactance as ordinates, to motional resistance as abscissæ, step by step, as the frequency is increased, the points lie on a circle passing through the origin The theory of the phenomenon has been worked out to a first approximation, and shows that a circular graph should be obtained, that the principal diameter lies at the resonant frequency of the diaphragm, and that different receivers or types of receiver have different characteristic circular graphs From an examination of the circular graph of a receiver various mechanical and electrical constants of the instrument can be derived

---

3 *The Electrical Measurement of Wind Velocities* [1] *By* Professor J T Morris

---

MONDAY, SEPTEMBER 9

Discussion on the Gas Turbine [2]

The following Papers were then read —

1 *The Road Problem* *By* Sir John H A Macdonald, *K C B*, *F.R S* —See Reports, p 373

---

2 *The Acceleration of a Motor Car* [3] *By* H E Wimperis, *M A*

In the first part of this paper was given a simple graphical method of predicting from its design the acceleration and hill-climbing ability of a motor car In the first place a torque-speed curve is constructed, from this is deduced an acceleration-speed curve, and from this in turn is derived the acceleration-time graph In working out these curves a 15-h p car is taken as typical

The next part of the paper contained an account of the methods in use for the experimental measurement of the acceleration of a motor car The various advantages and disadvantages of these methods were discussed The author then gave the actual acceleration curves for the above-mentioned car as obtained by the use of a recording accelerometer Two cases were taken, (*a*) when starting as in a race, and (*b*) when starting as in ordinary running The predicted and actual curves were compared and the differences analysed The author showed that the choking of the carburettor causes a material loss of acceleration on starting

The paper concluded with a reference to the considerations which influence what may be termed 'ideal acceleration,' and pointed out that this ideal is incapable of attainment with cars as at present constructed.

---

[1] See *The Electrician*, October 4, 1912 [2] *Ibid* September 13, 1912
[3] See *The Engineer*, September 27, 1912.

3 *Experimental Investigation of the Transmission of Heat*.[1] *By* Dr C N LAUDER *and* Professor PETAVEL, *F R S.*

4 *Some New Gyroscope Apparatus.* *By* Dr J G GRAY *and* G BURNSIDE

TUESDAY, SEPTEMBER 10

The following Papers were read .—

1 *Experiments on 'Suction' or Interaction between passing Vessels.* *By* Professor A H GIBSON, *D Sc* , *and* J HANNAY THOMPSON, *M Sc* , *M Inst C E*

In view of the general lack of experimental data as to the magnitude of the mutual forces involved in the cases of interaction between two vessels moving in parallel paths in close proximity, and as to their effective range of action, the authors decided to carry out a series of experiments to investigate these points on boats of sufficiently large size to enable the results to be applied with some confidence to seagoing vessels The vessels used were the steam-yacht 'Princess Louise' and a motor-boat Each is propelled by a single screw, and their details are as follow —

Vessel	Length between Perpendiculars	Beam	Draught	Displacement	Rudder Area
	Ft In	Ft In			
'Princess Louise'	88 6	13 0	6 ft forward 7 ft aft	—	—
Motor-boat	29 6	6 9	2 ft 3 in	—	100 sq in

Two sets of experiments were carried out In the first the helm of the motor-boat was lashed amidships, with the vessels on parallel paths, and its behaviour was noted when at different lateral distances, and when the boats were moving at different absolute and relative speeds Its position relative to the 'Princess Louise' was determined by angular measurements taken from the latter vessel at intervals of fifteen seconds Pressures at a series of corresponding points on the two sides of the motor-boat were measured at the same instants, with a view to determining the lateral forces involved.

The second series of experiments was devoted to a determination of the helm angle necessary to maintain the course of the motor-boat when in different positions relative to the larger vessel

Owing to possible collision risks the maximum speed was limited to six knots, which, in the case of the 'Princess Louise,' corresponds to eighteen knots in a vessel of the size of the 'Olympic' The results show that with both vessels moving at about this speed with helms amidships the smaller vessel is drawn into collision from any lateral distance less than a hundred feet (three and a half lengths of the smaller vessel) The precise behaviour depends largely on the relative and absolute speeds of the vessels and on their initial distance apart and initial relative position These points were discussed in the paper, as was the question of the helm angle required to prevent collision.

The authors are of opinion that the experiments prove conclusively that the forces involved during interaction are much greater than has been generally realised hitherto, while they have been particularly impressed by the rapidity with which collision usually follows the first sign of any interaction.

[1] See *The Electrical Review*, October 4, 1912.

2. *Problems in Propulsion in Air and Water.* *By* Professor J B HENDERSON

3 *Marine Propulsion by Electric Transmission* [1] *By* H A MAVOR

4 *Lifeboats on Ocean-going Ships and their Manipulation* *By* AXEL WELIN

The urgent necessity for revising present regulations referring to life-saving appliances at sea has recently been brought home with terrible force to the public mind Anticipating the ultimate results of the international deliberations at present in progress, the United States Government have already stipulated that every ocean-going passenger-steamer must provide sufficient boat-accommodation for every soul on board

To the lay mind such a rule must appear perfectly reasonable, seeing that no objection on the ground of expense can be permissible in a matter of this nature But it must be borne in mind that the mere fact of carrying a full complement of lifeboats implies no guarantee of safety Unless the boats can be readily manned and launched with a fair degree of certainty, they only constitute so much lumber uselessly carried about And it may be categorically stated that there are a large number of ships now in commission on which boats cannot be efficiently arranged to accommodate everybody on board

Considerable improvement may, however, be effected in the conditions hitherto prevailing, and it may safely be said that all the better-class passenger-carrying companies are giving the matter most careful attention The general adoption of wireless communication between ships, and also the success of anti-rolling tanks, have enormously augmented the value of the lifeboats in cases of emergency The last-mentioned invention practically removes the risk of boats getting crushed against the side of the ship when lowering in bad weather, and wireless telegraphy has reduced the question to one of providing means for transferring people from one ship to another in case of disaster Strong seaworthy boats, with the largest obtainable displacement for a given length, will now best meet the requirements, a high degree of navigability being of much less importance than formerly Detachable deck-houses, life-rafts, and the like, are, in the author's opinion, of very limited value

On account of the continually increasing height of modern ships, the old question of substituting wire ropes for the usual manila falls has come up again with renewed force The problem is, however, one of considerable difficulty in view of the ever-varying conditions under which the launching of the boats may have to be carried out

The first ship to obtain a really efficient davit installation of this nature is the ss 'Imperator,' of the Hamburg-Amerika Line, on which the majority of the boats stand some 70 feet above the water-line The launching of boats on this vessel may be effected in from forty to fifty seconds, and a special adjusting-gear permits of the boat descending at any required angle—a point of the greatest importance The hoisting is done by means of an electrically-driven 'fore-and-aft' transmission shaft provided with 'friction-drivers,' each boat being handled quite independently of the others The largest lifeboats are capable of accommodating seventy-six people, and weigh, fully loaded, approximately eight tons each

5 *The Distribution of Pressure on Inclined Aerocurves* *By* A P THURSTON

6 *The Control of Aeroplanes* [2] *By* Professor H CHATLEY.

[1] See *The Electrical Review*, September 20, 1912.
[2] See *Engineering*, September 27, 1912

WEDNESDAY, SEPTEMBER 11

The following Papers were read :—

1 *The Experimental Determination of the Stresses in Springs and other Bodies by Optical and Electrical Methods* [1] *By* Professor E G COKER, *M A*

Usually the chief difficulties in determining the state of stress in a body arise from the great variations of stress intensity which occur owing to its complicated shape and the loading, and, further, in the case of springs where plates are built up into a matrix, the rubbing friction between the surfaces is usually considerable enough to render the assumptions of perfect elasticity of the whole body somewhat unreliable for purposes of calculation, although each plate may be regarded as fulfilling the elastic conditions perfectly

Methods of experiment were described by optical and electrical methods of general application to stress problems

In the first method, models of springs are constructed of transparent materials for which it is shown that the stress distribution is very similar to that in steel These models permit of determinations of the difference of principal stresses at any point, and an important result is that the optical effect of a pure shear is proportional to twice the numerical value of one of the principal stresses

Examples of plate springs and flat-coiled springs were considered in detail, and the general distribution of stress illustrated by diagrams and natural-colour photographs of springs viewed in polarised light

The second method depends on the fact that steel and other metals when subjected to stress within the elastic limit experience a change of temperature—a diminution for tension stress and an increase for compression stress—proportional to the stress The effect at any point, therefore, is due to the sum of the principal stresses, and in cases of pure shear the effect is zero—a noteworthy difference from the first method Examples of tension, compression, bending, and shear experiments were described showing the applications of the electrical method

The paper described some attempts to utilise the difference in the electrical condition of stressed and unstressed metals for determining the stresses in materials

2 *Alternating Load Tests* [2] *By* BERNARD P HAIGH, *B Sc*

This paper dealt with the testing of wire specimens under pulsating loads, the pull being applied in a sine-wave by a machine comprising an electro-magnet supplied with alternating current The pull of such a magnet varies between zero and a maximum in a sine-wave with twice the frequency of the alternating current supplied, and the maximum pull is proportional to $(E \div C)^2$, where E and C are respectively the voltage and frequency of the current

The wire specimen is attached at its lower end to an armature which vibrates above the pole-face of the magnet, the magnetic circuit being arranged so as to give as light an armature as practicable The conditions necessary to ensure that the pull is independent of the range of vibration are discussed, and also the means by which the forces absorbed in accelerating the mass of the armature in its harmonic motion are compensated The vibrating armature is carried on springs adjusted to such a stiffness that the force exerted under any given deflection is equal to that required for the acceleration of the mass of the armature in that amplitude at the particular frequency of the test required In the instrument exhibited the springs are arranged to compensate at frequencies from 35 up to 120 extensions per second, and are adjusted by an experimental method employing 'resonance' The springs are also arranged to hold the armature in position, and as no guides are employed it is unnecessary to make any allowance

[1] See *Engineering*, September 20, 1912. [2] *Ibid* November 22, 1912

for friction. The value of the pull is calculated from the readings of the frequency and the voltage induced in a special measuring coil, which is wound close to the armature so that the flux measured is independent of leakage. The 'factor' of the instrument is determined experimentally by a method in which a standardised spring is substituted in place of the specimen, and a heavy mass is attached to the armature to reduce the amplitude of vibration. The maximum value of the magnetic pull is double that of the mean value which is thus determined. It was shown that the influence on the wave of pull of higher harmonics in the wave of E.M.F. is small, as only the fifth and seventh harmonics are active. A search-coil is provided in the instrument for checking their values by means of an oscillograph.

Particulars were given of tests carried out with ductile and hard-drawn steel wires. From these it appears that specimens of a 0.47 per cent. carbon steel broke when tested under pulsating load, with about 85 per cent. of their breaking load under steady loads. A ductile low-carbon steel, on the other hand, broke with only 65 per cent. of the steady breaking load, *i.e.*, at a load close to the yield point. The extension of this material under pulsating load (20 per cent.) was very close to that obtained with steady load.

---

3. *Exposure Tests of Light Aluminium Alloys.* *By* Professor ERNEST WILSON.

During the past eleven years reports have been presented to the British Association at fairly regular intervals. The tests show that alloying commercial aluminium with copper, unaccompanied by iron, nickel or manganese, is not satisfactory. A 2.6 per cent. copper alloy has completely deteriorated in ten years and increased its electrical resistance 25 per cent. 'Duralumin' is a copper-manganese alloy of aluminium with the addition of about 0.5 per cent. magnesium. During the last year a specimen has increased its electrical resistance 5.15 per cent. It would be interesting to know if this is due to the comparatively large percentage of copper (3.5 to 5.5) which this alloy is stated to contain, or if the percentage of manganese (0.5 to 0.8) is too low. This alloy has attracted attention in that a breaking-load as high as 90,000 lb. can be obtained, if desired, according to treatment. Its specific electrical resistance at 15° C. is about twice that of commercial aluminium. A specimen of high-conductivity copper wire has increased its electrical resistance 1.2 per cent. in one year.

---

4. *The Féry Bomb Calorimeter.*[1] *By* ROBERT S. WHIPPLE.

The bomb form of calorimeter is now frequently employed for the determination of the calorific value of coal, because the combustion of the coal is more complete than in those calorimeters in which the oxygen is admitted at atmospheric pressure or at a pressure slightly above atmosphere.

The instrument designed by Professor C. Féry,[2] of the Ecole de Physique et de Chimie, Paris, is of the bomb type, being in general design somewhat similar to the well-known Mahler instrument, but greatly simplified in its details. The bomb consists of a light iron vessel weighing about one kilo, and having a capacity of about 250 c.c. supported in the centre of a brass vessel by two discs of constantan (an alloy of copper and nickel). As the mass of metal in the bomb is small and no water-jacket is used, the rise in temperature of the bomb due to the combustion of the coal is large, averaging about 20° C. when 0.5 gramme of coal is burnt. It is evident that with such a large temperature rise the measurements need not be made with the same degree of accuracy as in the case of the usual type of bomb calorimeter, in which the temperature rise amounts to only 2° or 3° C. for the same quantity of coal.

The temperature rise is measured by the thermo-electric force generated by the constantan discs and the iron bomb, the surrounding envelope acting as the

[1] See *The Electrician*, September 13, 1912.

[2] See also 'Nouvelle Bombe Calorimétrique,' by C. Féry, *Journal de Physique*, p. 550, July 1912, and *Génie Civil*, May 25, 1912.

cold junction of the thermo couples These couples give an electromotive force of 40 micro-volts per degree C., giving on a pointer galvanometer a deflection of 60 mm. for a rise of 20° C It is thus possible to estimate the temperature rise of the bomb to at least $\frac{1}{5}$° C or to $\frac{1}{300}$ of the total rise in temperature

The loss of heat from the bomb is due to three causes: (1) conduction along the constantan discs; (2) convection currents in the air-space surrounding the bomb, and (3) radiation from the walls of the bomb

The effect of the loss by conduction is only to lower the maximum temperature obtainable as compared with what it would have been if the supporting discs were non-conductors The losses due to convection and radiation are negligible as compared with those due to conduction

The coal under examination is placed on a small tray in the bomb, the latter being filled with oxygen at about 200 lb pressure The coal is fired electrically, the maximum temperature rise on the galvanometer taking place about a minute and a half after ignition

Experiments show that the gas pressure can be varied from 150 lb to 250 lb, and the weight of coal burnt from 0 2 to 0 7 gramme, without any difference in the results obtained The instrument is standardised by burning either sugar, carbon, or standardised coal briquets, the calorific values of which are known

The instrument is easy to operate, and gives consistent results

---

5 *The Hysteresis Loss in Iron due to a combined Pulsating and Rotating Magnetic Field* [1] *By* THOMAS F WALL, *D Sc, M Eng, A M Inst C E*

There is a considerable amount of experimental data available with regard to the hysteresis loss in iron due to a pulsating magnetic field, and due to a rotating magnetic field, each acting separately, but, as far as the writer is aware, no experiments have been made to determine the hysteresis loss due to the simultaneous action of a pulsating magnetic field and a rotating magnetic field

Cases occur in practice in which the field pulsates and the iron at the same time rotates An example of this is the case of a plain series single-phase commutator motor, in which type of machine the iron of the cores is subjected to the pulsating field, due to an alternating current in the windings, while at the same time the rotor core is rotating The question then arises whether it is permissible to ascertain the hysteresis loss due to each source of loss as though it were acting alone, and then add the two quantities in order to obtain the total hysteresis loss. Otherwise stated Do the two hysteresis effects superpose without any mutual reaction? The experiments described in the paper were intended to decide this question.

The 'running down' method was used to separate out the hysteresis losses, and the points on the 'running down' curves were taken by means of a stroboscopic disc The machine used for the experiments had ball bearings and was therefore particularly adapted for this method of testing.

The first part of the investigation consisted in determining the value of the rotational hysteresis torque for a series of values of direct current in the stator winding, and a curve was obtained showing the connection between these two quantities If, now, an alternating current of known wave form be supplied to the stator winding, the mean value of the retarding rotational hysteresis torque may be deduced from the above curve because, for each ordinate of the alternating wave of current the corresponding rotational hysteresis torque may be read off from the above curve, and thus a wave of hysteresis torque may be constructed The mean ordinate of this wave will give the mean rotational hysteresis torque for the given wave form of current, and is the quantity which is effective in producing the retardation This assumes that the pulsating hysteresis torque in the rotor has no influence on the rotational hysteresis torque. Of course the pulsating hysteresis itself cannot produce a retarding torque on the rotor. A curve was shown deduced in the way described and connecting the rotational hysteresis torque, and the alternating-current amperes, supplied to the stator winding.

[1] See *The Electrician*, September 20, 1912

The value of the rotational hysteresis torque was then found experimentally by means of 'running down' curves, for several values of the frequency of the stator current It was found that for very low frequencies (four cycles per second) the experimentally determined rotational hysteresis torque approached closely to the values deduced from the measurements with direct current in the stator winding At higher frequencies the hysteresis torque for a given alternating current became gradually less until a frequency of about twenty cycles per second was reached, when it remained constant over a large range of frequencies (twenty to fifty cycles per second)

6 *Rescue Apparatus for Coal Mines* *By* F Reid

7 *Experiments on the Weathering of Portland Stone* *By* Dr J S. Owens, *F G S , A M Inst C E*

This investigation was initiated by Dr Des Voeux and is being made for the Coal Smoke Abatement Society Its object is to find the connection between smoke and the well-known deterioration by sulphating of stones containing a large proportion of calcium or magnesium carbonate when exposed to city air

The effect of weathering upon the strength of such stones in tension and compression was measured

The stones were subjected to the following conditions for periods varying from 105 to 687 days —

(*a*) Broken without exposure
(*b*) Broken after exposure to natural conditions out of doors in the country and in London
(*c*) Broken after having been kept indoors in the country and in London
(*d*) Broken after having been exposed, while embedded in soot, to country and London air.

The experiments are still going on, four series of stones up to the present have been broken, and the results are as follows —

Series 1 — Thirty-nine Portland stone briquettes, cut without reference to their bedding planes, were broken in tension All these stones increased in strength, some more than others, thus confusing the issue, but embedding in soot had a distinctly injurious effect on the strength

Series 2 —Twenty-nine similar to Series 1 were broken in tension The percentage of water present was noted, as its presence influenced the strength adversely Stones exposed in London showed a less resistance than those exposed in the country

Series 3 —Eighteen stones broken in tension showed that the presence of $4\frac{1}{2}$ per cent water—that is, sufficient to saturate the stones—reduced the strength by about 40 per cent The stones being broken in tension this loss of strength could not be due to any form of bursting pressure by the water, as might occur with a saturated stone under compression The results also show that in calculations as to the strength of structures built of stone the amount of water present should be taken into account

Series 4 —Twenty-five 1-inch cubes of Portland stone were broken in compression All these were dried before breaking, and the results show in all cases that exposure to London air, or embedding in soot, caused considerable loss of strength, when compared with stones exposed under normal conditions in the country The compression tests were made in a Wicksteed machine, cardboard packing-pieces being placed between the specimens and the compression plates, and the loads were applied at a uniform rate

The results obtained in each series are promising, but they indicate that further tests dealing with a larger number of specimens in each group are desirable

8. *On the Importance of previous Magnetic History to Engineers*.[1] *By* Professor E. WILSON, B. C. CLAYTON, *and* A. E. POWER.

If iron be subjected to a considerable force of, say, 20 C.G.S. units, and be then tested for hysteresis loss, it is known that for a given value of the magnetic induction B, the loss may be considerably larger than would have been the case had the effects of previous magnetic history been wiped out by careful demagnetisation.[2] Experiments made with a 3-kilowatt 60-frequency transformer show that the watts due to hysteresis and eddy currents are increased 30 per cent. or more when B has a value of about 300, and the magnetising force for this value of B is increased by nearly 50 per cent. These results are confirmed by ballistic galvanometer tests with specimens of Stalloy and Lohys. In Stalloy the ergs per cycle per cubic centimetre are increased by as much as 45 per cent. for a value of B of 500. Experiment shows that these effects can persist, and are not so easily wiped out as might be supposed, and it is suggested that engineers should bear these facts in mind, especially when expecting accurate results from current transformers and meters employing iron cores.

---

9. *The Behaviour of Ductile Material during Torsional Straining.* *By* C. E. LARARD.

The author presented the following considerations with a view to discussion:—

(1) The exact recorded limit of 'proportionality between strain and stress' may depend on the instrument used and the degree of fineness to which it is possible to indicate the strain.

(2) The yield period in torsion and the yield load are dependent on the speed rate of loading. If the test be made very slowly there is no sudden plastic yield experienced similar to that obtained in the case where a test is carried out moderately quickly. In fact the stress-strain curve is smooth and continuous.

(3) The approximate laws of flow of ductile during twisting at a uniform angular velocity may be stated as follows:—

(*a*) The rate of increase of the torque with respect to time varies inversely as the time and therefore inversely as the strain or angle of twist.

(*b*) The acceleration, which decreases, or as it may be called the deceleration of the torque with respect to time varies inversely as the square of the time or inversely as the square of the angle of torsion.

(*c*) The relationship between torque and time, and therefore between torque and twist, follows the compound interest law.

(4) Two theories have been advanced to explain the method of fracturing of a specimen. The author's theory,[3] which may be stated: When the maximum torque is reached shearing takes place over an annulus near the periphery, the shearing extending from annulus to annulus of decreasing mean radius and under a diminishing value of the torque until, owing to the irregular form of the sheared area setting up a wedging action, a more or less central core of the material is fractured by tension.

A theory advanced by Dr. Wm. Garnett,[4] in which he suggests that the outside layers being in helical tension and the inside layers in compression, resulting in one cylindrical layer being in a state of pure shear so that the first part of the failure is due to tension of the outside annulus, while the second

[1] See *The Electrician*, September 13, 1912.

[2] See *Journ. Inst. Elec. Eng.*, vol. 34, pt. 170, p. 55; *Roy. Soc. Proc.*, A, vol. 83, 1909, p. 1; *Phys. Soc. Proc.*, vol. 23, pt. 4, June 15, 1911, and vol. 24, pt. 5, June 28, 1912.

[3] Winnipeg meeting of the British Association (see *Engineering*, September 3 and 10, 1909).

[4] In a discussion following the author's Paper before the Institute of Automobile Engineers, January 1911.

part and the flying apart of the two pieces of the specimen is due to sudden release in compression.

Lantern slides and kinematograph illustrations were given for cylindrical, hollow, square, and rectangular sections, as well as for the machine representing its operations. The projections, enormously enlarged, were made in a small fraction of the time required for the tests; so that the behaviour of the material was readily demonstrated. In the case of the wrought iron, the defects of the metal were made manifest, while the flow had the appearance of a turgid stream in motion.

The author gratefully acknowledged the receipt of a Government grant from the Royal Society, which has made it possible to conduct experiments which there is every reason to expect will be not only of scientific interest, but also of value in engineering developments at present pending.

Section H.—ANTHROPOLOGY

PRESIDENT OF THE SECTION.—PROFESSOR G. ELLIOT SMITH, M.A., M.D., F.R.S.

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

In a recent address Lord Morley referred to 'evolution' as 'the most overworked word in all the language of the day'; nevertheless, he was constrained to admit that, even when discussing such a theme as history and modern politics, 'we cannot do without it.' But to us in this Section, concerned as we are with the problems of man's nature and the gradual emergence of human structure, customs, and institutions, the facts of evolution form the very fabric the threads of which we are endeavouring to disentangle, and in such studies ideas of evolution find more obvious expression than most of us can detect in modern politics. In such circumstances we are peculiarly liable to the risk of 'overworking' not only the word evolution, but also the application of the idea of evolution to the material of our investigations.

My predecessor in the office of President of this Section last year uttered a protest against the tendency, to which British anthropologists of the present generation seem to be peculiarly prone, to read evolutionary ideas into many events in Man's history and the spread of his knowledge and culture in which careful investigation can detect no indubitable trace of any such influences having been at work.

I need offer no apology for repeating and emphasising some of the points brought forward in Dr. Rivers' deeply instructive Address, for his lucid and convincing account of the circumstances that had compelled him to change his attitude toward the main problems of the history of human society in Melanesia first brought home to me the fact, which I had not clearly realised until then, that in my own experience, working in a very different domain of anthropology on the opposite side of the world, I had passed through phases precisely analogous to those described so graphically by Dr. Rivers. He told us that in his first attempts to trace out 'the evolution of custom and institution' he started from the assumption that 'where similarities are found in different parts of the world they are due to independent origin and development, which in turn is ascribed to the fundamental similarity of the workings of the human mind all over the world, so that, given similar conditions, similar customs and institutions will come into existence and develop on the same lines.' But as he became more familiar with the materials of his research he found that such an attitude would not admit of an adequate explanation of the facts, and he was forced to confess that he 'had ignored considerations arising from racial mixture and the blending of cultures.'

I recall these statements to your recollection now, not merely for the purpose of emphasising the far-reaching significance of an Address which is certain to be looked back upon as one of the most distinctive and influential utterances from this presidential chair; nor yet with the object of telling you how, in the course

of my investigations upon the history of the people in the Nile Valley,[1] I also started out to search for evidences of evolution, but gradually came to realise that the facts of racial admixture and the blending of cultures were far more obtrusive and significant. My intention is rather to investigate the domain of anthropology in which unequivocal evolutionary factors have played, and are playing, a definite rôle, I refer to the study of Man's genealogy and the forces that determined the precise line of development his ancestors pursued and ultimately fashioned Man himself

I suppose it is inevitable in these days that one trained in biological ways of thought should approach the problems of anthropology with the idea of evolution as his guiding principle, but the conviction must be reached sooner or later, by everyone who conscientiously, and with an open mind, seeks to answer most of the questions relating to Man's history and achievements—certainly the chapters in that history which come within the scope of the last sixty centuries—that evolution yields a surprisingly small contribution to the solution of the difficulties which present themselves Most of the factors that call for investigation concerning the history of Man and his works are unquestionably the direct effects of migrations and the intermingling of races and cultures

But I would not have you misunderstand my meaning The current of evolution is running at least as strongly and moving mankind onward no less quickly than it did when it brought his ancestors to human rank, it is as potent as ever to alter his structure, even though the way in which 'selection' has been modified has deflected the stream Those who imagine that the strength and influence of evolutionary forces have waned forget the enormous length of time it has taken to fashion the human body. It has been amply sufficient for slowly developing changes, such as are taking place at present, to have transformed an Ape into human form Environment, however it may act, whether directly or indirectly, is still helping to shape the human form, and is affecting the development of Man's customs and achievements at least as powerfully as, if not more so than, ever before The effects of selection—not only what Darwin understood by the term 'sexual' selection, but also what we have learned to call 'organic' and 'social' selection—are certainly emphasised by the heightened powers of discrimination which the intelligence and the fashions of civilised Man create We have every reason for believing, therefore, that the forces of evolution are still operating with undiminished vigour, but all the evidence that I have to bring before you goes to show that such forces act as a rule very slowly and imperceptibly, and need vast spans of time for the production of their effects In studying Man's past history we find no clear evidence, or even suggestion, of any such sudden jumps or 'mutations' as students of other branches of biology are calling to their aid to solve their difficulties, as a sort of magic carpet to convey them across awkward chasms in their evolutionary route

The Negro was quite as definitely negroid when we first meet with his sixty-centuries-old remains as he is now the narrow-headed brunette of small stature, who has dwelt around the shores of the Mediterranean since the dawn of history, was almost, if not quite, as definitely differentiated from the round-headed Armenoid of Western Asia at the end of the Stone Age as are their modern representatives, and all the millennia of exposure of their scattered descendants to vastly different climates and conditions of life have produced amazingly little effect upon their physical characteristics Further evidence may perhaps lend some measure of confirmation to the contention of Professor Boas,[2] that the uprooting of European people and their transference to America leads to an immediate effect upon the physical characters of such of their progeny as may happen to be born in the new environment; but while not denying the possibility that such an influence may be exerted, no anthropologist, however strongly he may be inclined to accept evidence in support of such a contention, can seriously take Professor Boas's data or the inferences he draws from them at his valuation Professor Boas would have us believe that the forces of environment which produce little or no effect upon the growing child (of aliens in New York), who happened to be born in Europe immediately before his parents emigrated,

[1] *The Ancient Egyptians,* 1911

[2] 'Changes in Bodily Form of Descendants of Immigrants,' *United States Government Reports,* 1910, 1911

can, nevertheless, so influence the germ-plasm of his parents that their American-born progeny will be instantaneously modified I know that it is easy to find parallels from biology, and especially from botany, to justify such an influence on the germ-plasm in the case of sudden changes of temperature, climate, soil, and other conditions of life, but until Professor Boas has dealt more exhaustively than he has, even in his second report, with the possibility of racial admixture as the obvious explanation of his statistics, and excluded it definitely, anthropologists must continue to view his data and the inferences from them with the most profound suspicion

I for one am quite prepared, if not to admit, at any rate to recognise the possibility that a new environment might produce immediate changes in the physical characteristics of the human body The multiplicity of internal secretions that recent research in physiology has shown to influence the growth of the various tissues of the body, and the immediate effects of a slight increase or diminution in the activity of the glands providing such secretions, which *may* perhaps be caused by new dietetic, climatic, or other conditions, are quite sufficient to suggest that the observer must keep his mind open impartially to view new observations concerning the immediate effect of a new environment on individuals, such as might conceivably afford a handle for the forces of natural selection to seize hold of and produce changes in the progeny of the altered parents, but there is a vast difference between admitting the *possibility* and recognising the *proof* of such an hypothesis, and I am still entirely sceptical of Professor Boas's so-called proofs One is certainly not the more disposed to accept such hypotheses when the attempt is made to bolster them up with a tissue of statements intended to minimise or even deny those physical, mental, and moral distinctions between different races of mankind,[3] the results of many millennia of years of differentiation, the reality of which is substantiated by the whole history of the world and the experience of those who have watched the intercourse of the various peoples

Difference of race implies a real and deep rooted distinction in physical, mental, and moral qualities, and the contrasts in the achievements of the various peoples cannot be explained away by lack of opportunities, in face of the patent fact that among the most backward races of the present day are some that first came into contact with, or even were the founders of, civilisation, and were most favourably placed for acquiring culture and material supremacy

It is not, however, with such contentious matters as the precise mode of operation of evolution at the present day that I propose to deal, nor yet with the discussion of when and how the races of mankind became specialised and differentiated the one from the other It is the much older story of the origin of Man himself and the first glimmerings of human characteristics amidst even the remotest of his ancestors to which I invite you to give some consideration to-day

In a recently published book[4] the statement is made that 'the uncertainties as to Man's pedigree and antiquity are still great, and it is undeniably difficult to discover the factors in his emergence and ascent' There is undoubtedly the widest divergence of opinion as to the precise pedigree, nevertheless, there seems to me to be ample evidence now available to justify us sketching the genealogy of Man and confidently drawing up his pedigree as far back as Eocene times—a matter of a million years or so—with at least as much certainty of detail and completeness as in the case of any other recent mammal, and if all the factors in his emergence are not yet known, there is one unquestionable, tangible factor that we can seize hold of and examine—the steady and uniform development of the brain along a well-defined course throughout the Primates right up to Man—which must give us the fundamental reason for 'Man's emergence and ascent,' whatever other factors may contribute toward that consummation

We have this advantage over most of our predecessors, in approaching the consideration of the problems of the gradual emergence of human traits from the uncouth simian features of our ancestors, that the main contention, the fact of the 'Descent of Man,' is now generally admitted, and it is no part of our task to discuss more or less irrelevant side-issues, born of prejudice, superstition, and

[3] *The Mind of Primitive Man*, 1911

[4] J A Thomson and P Geddes, *Evolution*, 1912, p 102.

ignorance. Moreover, we are able to command a vast army of newly discovered facts and attack the difficulties at issue in ways that were not open to those who went before us.

In these circumstances it seems to me that I may perform a useful service by setting forth the views which my studies—both of the facts of Nature and of the writings of contemporary biologists—have led me to adopt concerning Man's genealogy, from the remote period when his ancestral line branched off from those of the other mammalian orders, and to make the attempt to appreciate the nature of the factors that determined each upward step in his march toward the supreme position among intelligent beings.

In spite of all the precise knowledge, not only of the structure and functions, but even of the 'blood relationships,' using that term in its literal as well as its metaphorical sense, of the Apes and Men, it is surprising that there should be so little agreement among leading authorities as to the precise line of Man's ancestry. Biologists do not seem to be exempt from that spirit of unrest which is abroad at the present time, and there seems to be a strange reluctance to admit the obvious. Some zoologists try to persuade us that Man is not nearly related to the Old-World Apes, and seek for closer affinities with the New-World Apes, or even the Lemurs; others, again, exclude the Lemurs altogether from the Order Primates, or, on the other hand, would eliminate the Platyrrhine Monkeys from Man's genealogy; yet others claim a diphyletic origin for Man from the Apes. I do not propose to enter into the discussion of these problems[5] here, but rather, taking for granted the genealogical line which I, in agreement with many zoologists, believe to be a close approximation to the real line of descent,[6] attempt to find an explanation of how each of the more significant advances was brought about in the course of Man's evolution.

This theme, in one form or another, has often formed the subject of Presidential Addresses before this Section. The last time the Association met in Scotland the late Professor Cunningham, whose death since then we all so deeply deplore, presided over this Section, and dealt with[7] certain highly technical aspects of the subject in his own characteristically lucid manner. But though only eleven years have elapsed since then, the additions to our knowledge of comparative anatomy, especially that relating to the brain, have been so great and so fundamental that we can regard the problems discussed by him from a very different and, I think, more intimate and instructive point of view.

We no longer look, as he did, to that small patch of cortex in the left cerebral hemisphere, which has long been supposed to be the storehouse of the motor memories of articulate speech, as being the likeliest region to supply the key to the secret of Man's mental pre-eminence. Since Pierre Marie[8] expressed his disbelief in any such so-called motor speech-centre, many physiologists and physicians have become sceptical as to the ability of the left inferior frontal convolution to control the mere muscular movements that produce speech. But even if we grant the basal contention upon which Professor Cunningham's argument was founded (as I think we are justified in doing, in spite of the writings of Marie and his followers), we cannot be said to explain the evolution of the modern steamship when we describe the steering-wheel which directs its course.

Speech is a manifestation of the intelligence that depends upon the activity and co-operation of most parts of a large and highly organised cerebral cortex, acting as a whole; and what we have to discover is not so much how a particular series of groups of muscles bring about the mere motor acts of phonation and articulation, but what is the nature of the living mechanism which enables the mind to appreciate the multiplicity of sounds and other sensations, and to record such sensation-factors so that they may be recalled in memory and brought into relation as percepts with other sensation-factors in conscious experience, and made use of as guides to the realisation of the nature of causes and effects in the

[5] A critical examination of some of these views will be found in Prof. Sollas' Presidential Address to the Geological Society of London, February 1910.

[6] The simian stages of this genealogy are admirably expressed in a diagram made by Prof. Arthur Keith for his Hunterian Lectures 'On Certain Phases in the Evolution of Man,' *Brit. Med. Journ.*, April 6, 1912, p. 788.

[7] *Brit. Assoc. Report*, 1901, p. 776.

[8] 'L'Aphasie,' *Semaine Médicale*, 1906, p. 241.

events taking place around the individual it is the evolution of the cortex which makes possible this wide association of sounds and ideas, and this learning by experience that is important, rather than the mere instrument which regulates the emission of sounds that we learn to associate each with its appropriate idea Charles Darwin recognised this fact quite definitely, and expressed it with his usual directness,[9] when he said, 'It is not the mere articulation which is our distinguishing character, for parrots and other birds possess this power Nor is it the mere capacity of connecting definite sounds with definite ideas; for it is certain that some parrots which have been taught to speak connect unerringly words with things and persons with events The lower animals differ from Man solely in his almost infinitely larger power of associating together the most diversified sounds and ideas; and this obviously depends on the high development of his mental powers '

What I propose to attempt is to put into serial order those vertebrates which we have reason to believe are the nearest relatives to Man's ancestors now available for examination, and to determine what outstanding changes in the structure of the cerebral hemispheres have taken place at each upward step that may help to explain the gradual acquirement of the distinctively human mental faculties, which, by immeasurably increasing the power of adaptation to varying circumstances and modifying the process of sexual selection, have made Man what he is at present

A numerous band of zoologists and psychologists have collected a large mass of accurate information relating to the behaviour and intelligence of animals, with which Darwin, Huxley Tylor and many recent writers have familiarised students of anthropology It is not my intention to attempt to summarise or deal directly with these problems of comparative psychology

But there has been accumulating during the last few years, thanks largely to the efforts of Oskar and Cécile Vogt, Karl Brodmann, and many others [10] the material which will eventually enable us to correlate these differences in habits and behaviour in different mammals with structural differences in their brains, and in this Address I propose to discuss with you what light such investigations can throw upon the problems of Man's origin and the evolution of the instrument of his intelligence If in my attempts to interpret the significance of the progressive modifications, which we can demonstrate in the brains of the series of mammals I have selected, I shall give utterance to the crudest psychological conceptions, you must not credit this entirely to my ignorance of the teachings of psychology, but partly to the fact that so far we have been able only dimly to realise the nature of the processes that are taking place in the cerebral cortex, and it is safer to use the crudest forms of expression, so as not to delude you into the belief, which more precise terms might suggest, that our knowledge had yet attained to any degree of completeness or exactitude

We know something of the differences in behaviour of a series of Primates and of the variations in their responses to electrical stimulation of their brains How far can these differences be correlated with structural distinctions in their brains? And how far can such information be used to explain the evolution of our own brain, which supplies to each of us the only real knowledge of consciousness we possess? These are the questions that we are striving to answer

The class Mammalia, to which Man belongs is distinguished from all other vertebrates by the size and high development of the brain and by the fact that, to a much greater degree than in any other class, a progressive increase in the size of the brain, and more especially of the cerebral cortex becomes imperative in each successive epoch if its possessor is to maintain itself in free and open competition with its fellows It was the advance in brain structure in far greater measure than anything else that determined the evolution of mammals,[11] and it

[9] *The Descent of Man* p 130 in the 1901 reprint

[10] C and O Vogt, 'Zur Kenntnis der elektrisch erregbaren Hirnrinden-Gebiete bei den Saugetieren,' *Journ f Psych u Neur*, Bd VIII, 1907, p 280 K Brodmann, *Vergleichende Lokalisationslehre der Grosshirnrinde*, Leipzig, 1909

[11] In opening the discussion on the 'Origin of Mammals' at the meetings of Section D, last year, I developed this argument (*Brit Assoc Reports,* 1911, p 424)

has been wholly responsible for their dominant position, their world-wide distribution, and the plasticity which has manifested itself in the marvellous variety of adaptations to every mode of life which the mammals have undergone

If we search for the new feature in the brain which has made possible all their achievements it will be found in a cortical area to which eleven years ago I gave the name 'neopallium'[12]

In the lowlier vertebrates each of the avenues of the senses leads to a special part of the brain, and although there are free communications between the regions allotted to the olfactory, visual, auditory, tactile, and other senses, there is no instrument for the adequate blending of impressions reaching the brain through these different portals, or for the storing of impressions, so as to awaken in consciousness the different properties of an object which appeals to several different senses The lowlier vertebrates do not see, hear, or feel an object in the sense that we associate with these terms A biologically adequate stimulùs, such, for example, as a splash in a pond to a frog, or the croaking of its fellows, will call forth an appropriate response; but an excitation such as would not normally come within the range of experience of the creature, however intense it may be, such as a loud noise from a gong, will leave it quite indifferent, because it lacks any mechanism to enable it to compare the novel stimulation either with former impressions or with its immediate effect upon other sense-organs, and to judge it in the light of such standards of comparison

This must not be confused with the complex reflexes found in all vertebrates, where a response, or a whole train of complicated acts, is excited only by a series of stimuli entering the nervous system through various avenues of the senses, and elaborating in the central nervous system what Professor Sherrington would call a 'common path' to the nuclei of the motor nerves that excite the muscles to produce the appropriate response

Now it must be evident that unless there is some mechanism (*a*) for storing impressions so that they may be revived—*i e*, recalled in associative memory at some later time, and (*b*) for blending in consciousness the sensory impulses entering the sensorium by different portals, there can be no learning by experience A fish that has swallowed a fly on a hook and got rid of the latter will repeat the process immediately, presumably because there is no intimate association in the brain between the receptor of the visual impression of the fly in the mid-brain and the receptor of the painful impression of the hook in the hind brain, and therefore nothing to inhibit the normal response of the animal to the adequate biological stimulus provided by the visual image of the fly, whenever it occurs again

Some faint glimmering of an elementary kind of judgment makes its appearance in reptiles, in which the tactile paths have made their way into the hitherto almost exclusively olfactory cerebral hemispheres, and established some definite representation for the sense of touch in this dominant part of the brain[13] The snake which smells out some food-material, and then tests it by feeling it with its tongue, is checking by means of one sensory perception the information gained through another sense it thus displays the germ of the power of contrasting the impressions and the memories of sensations reaching the brain by two distinct avenues of sense, from which eventually the power of instituting deliberate conscious judgments is developed

It is able to do so (and this is the important point for us to remember in this discussion) in virtue of the fact, which can be demonstrated by the comparative study of the structure of the brain, that both the senses of smell and touch are able not only to pour their impressions into contiguous and intimately associated areas of the cerebral cortex, but also because they are represented there by a mass of material serving as a storehouse for the impressions of these senses, which can be revived in memory

But such potentialities can be said to become first definitely established for

[12] 'The Natural Subdivision of the Cerebral Hemisphere,' *Journ Anat and Phys*, vol xxxv, 1901, p 431

[13] Arris and Gale Lectures on the Evolution of the Brain, *Lancet*, January 15, 1910, p 153

all the senses in mammals The neopallium of the mammal [14] provides a receptive organ for impressions of all the senses—touch, vision, and hearing, as well as taste and smell, among the rest—which enables the effects of all such perceptions to manifest themselves unified in consciousness, and to become recorded in some way so that they can be revived again, each discrete sensory impression or the one idea excited by all of them, in associative memory Moreover, it is the instrument by means of which all these perceptions, past and present, can be freely blended in consciousness, so that the animal is able to appreciate all the properties of any object, to whatever sense they may appeal, and can benefit by past experience, and so be educated

In spite of the opinion of Prof C J Herrick,[15] I maintain that the neopallium is a feature distinctive of the mammalian brain, and that it represents in itself the unity of the apparatus concerned with psychical phenomena, the *sensorium commune*, which Aristotle postulated as the counterpart of the unity of consciousness [16] I am well aware that psychologists may consider this the rankest heresy, to judge from the writings of my friend Dr William McDougall [17], but the anatomical evidence is quite definite and unequivocal that in the neopallium of the lowlier Mammalia we have a 'unitary organ the physical processes of which might be regarded as corresponding to the unity of consciousness' Moreover, it fulfils Aristotle's claim for his *sensorium commune* of possessing 'especially the perceptual functions that are common to the several senses'

Nothing that happens in this area in the course of its enormous expansion and differentiation in the higher mammals materially affects this fundamental purpose of the neopallium, which continues to remain a unifying organ that acts as a whole, though each part is favourably placed to receive and transmit to the rest its special quota to the sum-total of what we may call the materials of conscious life

Thus the area in which the tract from the eyes ends in the neopallium naturally becomes the mechanism for visual perception, but it also serves as a means of union between visual and other perceptual parts of the cortex, for if the eyes are destroyed, the visual area does not wholly atrophy, or again, in the intact individual the visual impression of an apple is capable of awakening memories of perceptions of its 'feel,' its weight, its smell and its taste, all of which were originally acquired by impressions made upon the receptive area of each of the senses concerned

The consciousness which resides, so to speak, in this neopallium, and is fed by the continual stream of sensory impressions pouring into it and awakening memories of past sensations, can express itself directly in the behaviour of the animal through the intermediation of a part of the neopallium itself, the so called motor area, which is not only kept in intimate relation with the muscles, tendons, and skin by sensory impressions, but controls the voluntary responses of the muscles of the opposite side of the body

The possession of this higher type of brain enormously widened the scope for the conscious and intelligent adaptation of the animal to varying surroundings; a sensory impression once received no longer remained only half an experience, which left no lasting impression behind it to influence behaviour in the future, or at most a perception uninfluenced by those simultaneously received by other sense-organs, and thus incapable of being checked, so to speak, and in the exercise of this newly acquired power of choice the way was opened for adaptations to varying environments entailing manifold structural modifications, in which the enhanced plasticity of the new type of animal found expression

Nature tried innumerable experiments with the new type of brain almost as soon as the humble Therapsid like mammal felt the impetus of its new-found

[14] I am omitting all reference to birds, in which a new formation makes its appearance in the cerebral hemisphere and performs functions in a sense analogous to those of the neopallium in mammals It is, however, a specialisation incapable of great extension, just as the structure and functions of a bird are so highly specialised for flight as to lose the high degree of plasticity of the primitive mammal

[15] 'The Morphology of the Forebrain in Amphibia and Reptilia,' *Journ Comp Neur and Psych*, October 1910, p 439

[16] See *op cit*, *Journ Anat and Phys*, vol xxxv, p 453

[17] *Body and Mind*, 1911, p 286

power of adaptation, and from its South African home began to wander throughout the world In turn the Prototherian and Metatherian types of brain were tried before the more adaptable scheme of the Eutherian brain was evolved.

The group of lowly Insectivora, including such creatures as Moles, Hedgehogs, and Shrews, persists to the present time to reveal the nature of the earliest Eutherian brain

The Insectivora have been able to persist in competition with more advanced mammals by reason of their small size, and the development of manifold varieties of protective specialisations and the adoption of habits to ensure their safety. In their spread throughout the world they eventually came to occupy practically the whole earth, with the remarkable exception of the Australasian and, except for a short time, South American regions, where their predecessors, the Metatheria, found a haven of refuge, which saved them from the extinction that would inevitably have been their fate if they had had to struggle for existence in competition with the more nimble-witted Eutheria, endowed with a superior type of brain.[18]

Among the Insectivora there is one group—perhaps worthy of ordinal distinction, the Menotyphla of Haeckel—which is of peculiar interest to the student of Primate and human genealogies

This group includes the Oriental Tree-Shrews and the African Jumping-Shrews The latter (Macroscelididæ), living in the original South African home of the Mammalia, present extraordinarily primitive features, linking them by close bonds of affinity to the Marsupials The Tree-Shrews (Tupaiidæ), however, which range from India to Java, while presenting very definite evidence of kinship to their humble African cousins, also display in the structure of their bodies positive evidence of relationship to the stem of the aristocratic Primate phylum

I need not discuss the evidence for these views, because it has recently been summarised most excellently by Dr W K Gregory[19] of New York

It will suffice to point out that, quite apart from the striking similarities produced by identical habits and habitats, there are many structural identities, not directly associated with such habits, which can be interpreted only as evidences of affinity

These Tree-Shrews are small squirrel-like animals which feed on 'insects and fruit, which they usually seek in trees, but also occasionally on the ground When feeding they often sit on their haunches, holding the food, after the manner of squirrels, in their forepaws'[20] They are of 'lively disposition and great agility'[21] These vivacious, large-brained, little insectivores, linked by manifold bonds of relationship to some of the lowliest and most primitive mammals, present in the structure of their skull, teeth, and limbs undoubted evidence of a kinship, remote though none the less sure, with their compatriots the Malaysian Lemurs, and it is singularly fortunate for us in this inquiry that side by side there should have been preserved from the remote Eocene times, and possibly earlier still, these insectivores, which had almost become Primates, and a little primitive lemuroid, the Spectral Tarsier, which had only just assumed the characters of the Primate stock, when Nature fixed their types and preserved them throughout the ages, with relatively slight change, for us to study at the present day.

Thus we are able to investigate the influence of an arboreal mode of life in stimulating the progressive development of a primitive mammal, and to appreciate precisely what changes were necessary to convert the lively, agile *Ptilocercus*-like ancestor of the Primates into a real Primate

In the forerunners of the Mammalia the cerebral hemisphere was predominantly olfactory in function, and even when the true mammal emerged, and all the other senses received due representation in the neopallium, the animal's behaviour was still influenced to a much greater extent by smell impressions than by those of the other senses

This was due not only to the fact that the sense of smell had already installed

[18] *Vide* Arris and Gale Lectures, *op cit*, *supra*

[19] 'The Orders of Mammals,' *Bull. Amer Mus Nat Hist*, vol xxvii, 1910, p 321.

[20] Flower and Lydekker, *Mammals, Living and Extinct*, 1891, p 618.

[21] W. K Gregory, *op cit*, p 269, and pp 279, 280

its instruments in, and taken firm possession of, the cerebral hemisphere, long before the advent in this dominant part of the brain of any adequate representation of the other senses, but also, and chiefly, because to a small land-grubbing animal the guidance of smell impressions, whether in the search for food or as a means of recognition of friends or enemies, was much more serviceable than all the other senses. Thus the small creature's mental life was lived essentially in an atmosphere of odours, and every object in the outside world was judged primarily and predominantly by its smell; the senses of touch, vision, and hearing were merely auxiliary to the compelling influence of smell.

Once such a creature left the solid earth and took to an aquatic or an arboreal life all this was changed, for away from the ground the guidance of the olfactory sense lost much of its usefulness, and in the case of aquatic mammals the whole smell apparatus atrophied, and in some cases vanished. We need not stop to consider the aquatic mammal, because a life in the water calls for such marked specialisation of structure that such creatures disappear from the race for mammalian supremacy. But the case is very different with arboreal mammals. Life amidst the branches limits the usefulness of olfactory organs, but it is favourable to the high development of vision, touch, and hearing. Moreover, it demands an agility and quickness of movement that necessitates an efficient motor cortex to control and co-ordinate such actions as an arboreal mode of life demands (and secures, by the survival only of those so fitted), and also a well-developed muscular sensibility to enable such acts to be carried out with precision and quickness. In the struggle for existence, therefore, all arboreal mammals, such as the Tree-Shrews, suffer a marked diminution of their olfactory apparatus, and develop a considerable neopallium, in which relatively large areas are given up to visual, tactile, acoustic, kinæsthetic and motor functions, as well as to the purpose of providing a mechanism for mutually blending in consciousness the effects of the impressions pouring in through the avenues of these senses.

Thus a more equable balance of the representation of the senses is brought about in the large brain of the arboreal animal, and its mode of life encourages and makes indispensable the acquisition of agility. Moreover, these modifications do not interfere with the primitive characters of limb and body. These small arboreal creatures were thus free to develop their brains and maintain all the plasticity of a generalised structure, which eventually enabled them to go far in the process of adaptation to almost any circumstances that presented themselves.

Towards the close of the Cretaceous period some small arboreal Shrew-like creature took another step in advance, which was fraught with the most far-reaching consequences, for it marked the birth of the Primates and the definite branching off from the other mammals of the line of man's ancestry.

A noteworthy further reduction in the size of the olfactory parts of the brain, such as is seen in that of *Tarsius*,[22] quite emancipated the creature from the dominating influence of olfactory impressions, the sway of which was already shaken, but not quite overcome, when its Tupaioid ancestor took to an arboreal life. This change was associated with an enormous development of the visual cortex in the neopallium, which not only increased in extent so as far to exceed that of *Tupaia*, but also became more highly specialised in structure. Thus, in the primitive Primate vision entirely usurped the controlling place once occupied by smell; but the significance of this change is not to be measured merely as the substitution of one sense for another. The visual area of cortex is part of the neopallium, and when its importance thus became enhanced the whole of the neopallium felt the influence of the changed conditions. The sense of touch also shared in the effects, for tactile impressions and the related kinæsthetic sensibility, the importance of which to an agile tree-living animal is obvious, assist vision in the conscious appreciation of the nature and the various properties of the things seen and in learning to perform agile actions which are guided by vision.

An arboreal life also added to the importance of the sense of hearing, and the cortical representation of this sense exhibits a noteworthy increase in the

[22] 'On the Morphology of the Brain in the Mammalia, with Special Reference to that of the Lemurs, Recent and Extinct,' *Trans. Linn. Soc. Lond.*, second series; *Zoology*, vol. viii., part 10, February 1903.

Primates, the significance of which it would be difficult to exaggerate in the later stages, when the simian are giving place to the distinctively human characteristics.

The high specialisation of the sense of sight awakened in the creature the curiosity to examine the objects around it with closer minuteness, and supplied guidance to the hands in executing more precise and more skilled movements than the Tree-Shrew attempts Such habits not only tended to develop the motor cortex itself, trained the tactile and kinæsthetic senses, and linked up their cortical areas in bonds of more intimate associations with the visual cortex, but they stimulated the process of specialisation within or alongside the motor cortex of a mechanism for regulating the action of that cortex itself—an organ of attention which co-ordinated the activities of the whole neopallium so as the more efficiently to regulate the various centres controlling the muscles of the whole body In this way not only is the guidance of all the senses secured, but the way is opened for all the muscles of the body to act harmoniously so as to permit the concentration of their action for the performance at one moment of some delicate and finely adjusted movement

In some such way as this there was evolved from the motor area itself, in the form of an outgrowth placed at first immediately in front of it, a formation, which attains much larger dimensions and a more pronounced specialisation of structure in the Primates than in any other order, it is the germ of that great prefrontal area of the human brain which is said to be 'concerned with attention and the general orderly co ordination of psychic processes,'[23] and as such is, in far greater measure than any other part of the brain, deserving of being regarded as the seat of the higher mental faculties and the crowning glory and distinction of the human fabric

But the high development of certain other parts of the cortex was necessary to minister to these high functions of the prefrontal cortex and to supply the materials, if the term can be applied to anything so immaterial as perceptions and memories, upon which its own activities are expended For before an animal like *Tarsius* could attempt to concentrate its attention upon the performance of some delicately skilled action, its large and highly specialised visual, tactile, and motor areas must have had impressed upon them countless numbers of records of things seen and felt and of memories of the experience acquired in performing innumerable simpler acts

Whether the exceedingly primitive *Tarsius*-like Primates, of which I have been speaking, originated in the extreme south-west of Asia, where its modern representative now lives, or in North America, it is not possible to say with certainty, but the fact that the Eocene beds of North America contain remains of both the *Tarsius*-like *Anaptomorphus* and *Tupaia*-like Insectivores[24] seems to suggest that North America may have been the original home of the Primate phylum, and the centre from which, quite early in Eocene times, there radiated to South America Asia, Europe, and Africa the ancestors not only of the Tarsier itself, but of the Lemurs also, as well as specialised varieties of lemuroids, such as *Adapis*, which may perhaps be related to the progenitors of the Lemurs What remained of the original undifferentiated Primate stock in North America became transformed into primitive monkeys of Platyrrhine type, from which in turn sprang not only the later New World apes, but also the Catarrhine or Old World apes, which were undoubtedly derived from primitive Platyrrhines, possibly after their migration into the Old World in Oligocene times, or perhaps even earlier

In the present state of our knowledge it is not possible to give the precise history of the wanderings of the early Primates For not only are there vast ages of time in which we lose sight of them altogether, but in addition we are still far from an agreement as to the intercontinental land-bridges along which our simian ancestors must have travelled in their wanderings How great are the discrepancies between the conclusions reached by leading authorities on this subject is revealed only too clearly in the recent monographs by Professor

[23] J S Bolton, 'The Functions of the Frontal Lobes,' *Brain*, 1903

[24] H F Osborn, *The Age of Mammals*, 1910, p 155

Osborn[25] and Dr Scharff,[26] and in the opinions of other writers which they set forth in these two books.

The extremely primitive and Metatheroid characters of the Jumping Shrews mark them out as the nearest approach to the original Eutherian mammal now living, and it is probable that South Africa, their present habitat, was not only the original home of mammals, but also the place where the Eutherian mammals were evolved In Upper Cretaceous times there was a direct land-bridge[27] from this South African home of the Jumping Shrews to the Southern Asiatic habitat of their Primate-like kinsmen, the Tree-Shrews, and also another broad tract linking Eastern Asia to North America So that there is no difficulty in realising how the Anaptomorphid Lemuroids or their immediate ancestors reached North America

It is now generally admitted that *Tarsius* is not only the most primitive Prosimian now living, but that it is much more intimately related to the monkeys than the true Lemurs are The fact that the earliest known fossil Primate, the Early Eocene *Anaptomorphus* of North America, so nearly resembles *Tarsius* further strengthens this view, and convinces us that in the Anaptomorphidæ we have the real progenitors of the Apes and Man

Now, in the middle of the Eocene period these Lemuroids, and in fact all trace of the Primates, disappear from North America, and for the rest of the Eocene and Oligocene periods neither the Tarsioids nor true monkeys, according to some leading authorities, can be traced, until, in the Miocene, Platyrrhine Apes suddenly make their appearance in Patagonia, and Catarrhine and Anthropoid Apes in Europe Even if we side with those who disagree with Professor W B Scott's opinion that the earliest monkeys in South America belong to the Miocene Age, and look upon them as Oligocene or Late Eocene,[28] there still remain a great many lacunæ in the fabric of our story

We are not concerned here with the problem of how *Tarsius* and the Lemurs came to the Old World It may have been the case that the original habitat of the Tarsioids ranged from North America to South-eastern Europe, and that the Tupaioid Insectivores, whose past and present representatives were distributed much in the same way, shared a similar fate The Lemurs also may have sprung from some Protarsioid form and spread into Asia, or, seeing that their earliest allies[29] are found in the Middle and Late Eocene beds of Europe, it is not impossible that they may have made their way from North America into Europe by means of Scharff's hypothetical Atlantis,[30] which according to him linked Mexico and the Antilles to Europe

But this is a problem that does not concern us in this inquiry For the Lemurs, even in the Eocene, had left the path that leads to the Apes, and, however interesting *Tarsius* itself may be, once its Eocene progenitors gave birth to true monkeys we become interested in them, and not in the wanderings of the unmodified Lemuroids themselves

As the facts of Comparative Anatomy point quite definitely to a kinship between the more primitive Platyrrhine monkeys of South America and the Catarrhines of the Old World, and also suggest that the latter must have passed through a Platyrrhine stage in the course of their evolution, we must first consider the nature of the wanderings that such kinships involve

In the Lower and Middle Eocene of North America we find primitive Tarsioids, then in the Miocene [or late Eocene] in South America true Platyrrhines occur, and in the European Miocene Catarrhine and Anthropoid Apes What working hypothesis can be framed to fill in the extensive lacunæ in this story Palæontology tells us little more than this of the evolution of the Apes Hence we must fall back upon the teaching of Comparative Anatomy

The appearance in the Egyptian Fayoum as early as the Oligocene, according to Schlosser,[31] of monkeys presenting primitive traits suggestive of the

[25] H F Osborn, *The Age of Mammals*, New York, 1910

[26] R F Scharff, *Distribution and Origin of Life in America*, London 1911

[27] See Dr Ortmann's map in Scharff, *op cit*, facing p 292

[28] Dr von Ihering, quoted by Scharff, *op cit*, p 393

[29] *Adapis* and the *Tarsius*-like *Necrolemur*

[30] *Op cit*, see map 14, facing p 280

[31] Max Schlosser, *Zool Anzeiger*, March 1, 1910, p 500

New World Platyrrhines, in association with others that seem to suggest a very early Anthropoid, the *Propliopithecus Haeckeli* (Schlosser), is a most suggestive discovery. It accords, however, with the scheme of Primate evolution and migrations which is based upon the other evidence at our disposal; so that some such hypothesis as I shall now sketch naturally shapes itself in our minds.

As the Tarsioids entirely disappeared from North America by the Middle Eocene and are not known to occur anywhere else in the world, either in past or present times, except as the Spectral Tarsier of the South-eastern corner of Asia, we must assume that some Tarsioids took refuge in Asia, which they reached, if they were not there before, by Scharff's hypothetical trans-Pacific land-bridge in the Early Eocene, before their brethren disappeared from North America.

But it seems probable that some of the Tarsioids that lived in North America in Early Eocene times became transformed from Prosimiæ into true monkeys of a very primitive Platyrrhine type, distinguished, among other things, from their Lemuroid ancestors by a much higher development of the power of skilled movement, of which tangible evidence is forthcoming in the considerably larger and more highly specialised motor area of their modern descendants.[32]

The true monkey seizes its food with its hands, and not with its jaws, as the Lemur does.

A noteworthy increase occurred also in the visual cortex, and especially in those outlying parts of it which do not receive impressions directly from the optic tracts, but presumably are concerned with the storing of visual memories and associating them with tactile and acoustic impressions.

There is a corresponding, and perhaps relatively greater, change in the auditory centres.

Although the fossil beds of America have not yet yielded up the intermediate stages in these transformations, we have in the Middle Eocene Notharctids, those curiously half-formed Platyrrhines, and others of their contemporaries,[33] some evidence of the experiments Nature was performing in the process of creating Apes. And if it be objected that it is mere conjecture to say that the Tarsioids which went southwards in America were transformed into Platyrrhine monkeys by the time they reached Patagonia, it must be remembered that the vast continent which formed the link between California and Patagonia in those days if we follow Scharff,[34] is now submerged, with all its relics of the birth and early history of the Apes. It is highly probable that some of the primitive Platyrrhines which were thus evolved spread from America into the Old World. Those that remained in the former continent spread south, leaving North America entirely without Primates, and in the relative seclusion of the South American forests they retained much of their primitive structure, but some of them sacrificed part of the advantage, from the point of view of mental evolution, gained when they took the upward step from the Prosimian to the Simian status, by devoting the special skill they had acquired to developing the prehensile powers of their tails, rather than concentrating such potentialities in the more serviceable culture of their hands.

Their brethren who crossed into the Old World took the higher course, and eventually achieved the greater distinction, when they became especially expert in performing the most delicate movements with their hands.

Which of two land-bridges, trans-Pacific and trans-Atlantic, available in the Early Tertiary Age from Central America to Asia and Europe respectively,[35] the primitive monkeys traversed there is no definite evidence to indicate. For, while most writers assume that they went directly from North America to Western Asia, it must be borne in mind that the earliest remains of monkeys in the Old World occur in Egypt and Europe, and thus it is not altogether improbable that the Platyrrhine ancestors of the Catarrhines set out on their journey to the Old World by the trans-Atlantic route, and perhaps underwent the earlier stages of their further development in North Africa. For in the

[32] C. and O. Vogt, *op. cit.*, p. 391.

[33] H. F. Osborn, *The Age of Mammals*, p. 161, also *Bull. Amer. Mus. Nat. Hist.*, vol. xvi., 1902, Workman, *Amer. Journ. Sci.*, vol. xv., 1903, and Max Weber, *Saugetière*, 1904, p. 763.

[34] Scharff, *op. cit.*, fig. 14.

[35] *Ibid.*

Fayoum monkeys, described by Schlosser as belonging to the Oligocene Age, there is a strange association of Platyrrhine and Catarrhine traits.

In their new environment these primitive Catarrhines felt the impetus of their newly acquired faculties, and an army of variously specialised Apes set out to invade the rest of the warmer regions of the Old World. In the course of these differentiations some of the Catarrhines fell away in some respects from the high standard their ancestors had attained, the Baboons, for example, took to quadrupedal progression, and thereby sacrificed all chance of further advance in the Anthropoid direction. But in Early Oligocene times certain of the Catarrhines probably developed still further the powers of walking erect, which their remote Tarsioid ancestor possessed in some measure, and became modified in structure so as to be able to walk upright upon their hind limbs, and use their hands and arms for other purposes. Thus, one group of Catarrhines became transformed into Anthropoid Apes very soon after the evolution of the first monkey of the Old World.

The assumption of the erect attitude is not the simple matter that most anthropologists suppose it to be: it is not a question merely of learning to balance the body on the hinder extremities but, as Professor Keith has well shown,[36] it entailed profound structural changes for the fixation of the contents of the body so that the organs would not fall, and also the loss of the tail, so that the tail muscles could be turned to other uses as visceral supports, moreover, the freeing of the arms, which in a pronigrade animal, as Dr. Wood Jones has shown, are fixed supports for the muscles of respiration, interfered with this function of the extrathoracic muscles, and made the diaphragm the chief respiratory muscle. Thus was effected the most far-reaching changes in the mode of breathing. Such fundamental modifications of the structure and functions of the body must have been fashioned when the primitive Catarrhine was far more plastic than any of the modern Old World Apes we are familiar with, and I should not have been at all surprised, even without any knowledge of Schlosser's Oligocene *Propliopithecus*, to find that an erect Anthropoid Ape had already emerged from the Proto-Catarrhine stock soon after the close of the Eocene period.

In the modern Gibbon, which is a true Anthropoid, Nature has preserved for us with relatively only slight changes the type of the original ancestor of the phylum common to Man and the giant Apes.

The additional freedom which the degree of erectness of the Gibbon affords to the arms gave an immense impetus to the development of more highly skilled movement and a phenomenal agility, and such potentialities are the expression of still further stages of growth and elaboration of the brain. In all probability it is not strictly accurate to speak of the freeing of the arms as supplying the stimulus to the brain by permitting the acquisition of more highly skilled movements, expressed in a higher state of cultivation and growth of the motor cortex. There can be no question that the primary stimulus to the fuller use of the arms as organs, not of mere progression, but of prehension and the more skilled acts came from the steady growth and specialisation of the brain itself, but the consequences of the acquisition of this skill were the freeing of the arms and the possibility of still further cultivation of the powers of the hands, which no doubt reacted so as to call for yet further growth and specialisation of the brain. Thus, there was a reciprocal influence of brain and the erect attitude, both helping to achieve the result which various writers are too apt to attribute exclusively to one factor only.

That this explanation is the correct one is shown by the gradual increase in the size of the motor area, the degree of specialisation of the movements that become possible, and especially in the progressive expansion of the prefrontal area found at each step, when we compare Lemurs with Platyrrhines, the latter with Catarrhines, and these, in turn, with Anthropoids.[37]

This is especially seen in the increase in the control of the independent movements of the fingers. Such actions are very poorly developed in Lemurs, a little

[36] Keith, Hunterian Lectures on Certain Phases in the Evolution of Man, *Brit. Med. Journ.*, April 6, 1912, p. 788.

[37] C. and O. Vogt, *op. cit.*, pp. 392, 393, and 394, also Brodmann, *op. cit.*, *supra*.

better in the New World Apes, but they became well developed in the Old World Apes, and very highly skilled and controlled in all the Anthropoid Apes It was this gradual increase in skill of hand and arm which made it advantageous for the ancestors of the Gibbon to adopt, more definitely than *Tarsius* had done, the erect attitude and for their structure to become 'set' to make the best use of such skill

But, marked as are the changes that can be detected in the behaviour of the erect Gibbon, in the increased size and specialisation of its motor and prefrontal areas, of which the latter is an expression of an improved control over the functions of the cortex as a whole, there is a significant increase in the size of the area which intervenes between the visual, tactile, and auditory centres The growth and increased functional value of this parietal area, which from its position is obviously the place for storing the records of the complex states of consciousness, blended of visual, tactile, and auditory sensations, lie at the root of all the other changes in the brain, and the perfecting of the mechanism for supplying consciousness with these more perfect materials of experience, explains the increased ability to perform more highly skilled movements which, in turn, led to the adoption of the erect attitude, and thus freed the hands for the work they had for the first time become skilled to perform

So far in this address I have been attempting to sketch certain outstanding features of Man's ancestry with the object of offering some explanation of the factors which made possible the emergence of such a creature as Man We have seen that the adoption of an arboreal life by some small Insectivore-like creature, shortly before the dawn of the Tertiary period, and its subsequent cultivation of the sense of vision until it became a highly specialised Anaptomorphid, enabled Man's remotest Primate ancestor to escape from the domination of the sense of smell as the guiding influence of its life, and to cultivate its other senses, so as immensely to widen the sensory avenues by which the outside world could affect its conscious activities The arboreal life, which demanded great activity and agility, led to the special cultivation of skilled movements of the limbs, and such an acquirement was clearly facilitated in this group by the perfection of visual control, without which finely adjusted actions of the hands and feet could not easily be learned The acquisition of such skill in movement necessitated the increased perfection of the tactile and other sensory areas of the brain, so as the more nicely to control the adjustments and correlations of muscles essential for any precise action Thus, we have a chain of linked influences that follow on the specialisation of the visual apparatus in the brain of our primitive arboreal ancestor—the perfecting of touch and the acquirement of skill in action The heightened acuity of vision and the expansion of the cortical area for storing visual impressions, together with the growing importance of touch, and in a less measure, perhaps, of hearing, immensely widened the psychical content of the life of the Eocene Tarsioid in comparison with that of its contemporaries, but there is yet another factor which its mode of life called into play which was fraught with the most far-reaching possibilities in the creation of Man The co-ordination of large groups of muscles for the purpose of performing some precise action, which must be controlled during the stage of learning by tactile, kinæsthetic and visual impressions and memories—the fruits of experience—necessitated the formation of some cortical apparatus which would control and harmonise the activities of the various centres, regulating the muscular actions, and bringing the total sum of consciousness at any one moment to bear upon the performance of a given act Out of such a necessity as this there sprang in the early ancestor of Man—and, though in much less degree, in certain other phyla also—an outgrowth of the motor cortex, which became the mechanism for attention and the orderly regulation of the psychical processes

Thus, at the very dawn of the Tertiary period there were developed the germs of all the psychical greatness which, in the million or so of years that have followed, culminated in the human mind

But the early Primate stem attained this distinctive position of relative isolation, not merely by the development of its own members, but also by the rapid and divergent specialisation of other mammalian groups The enhanced plasticity conferred upon mammals by the development of a neopallial cortex, which enabled them to exercise, to an immeasurably greater degree than any of their predecessors had enjoyed, what we may without inaccuracy term intelligent

choice, found immediate expression in a bewildering variety of specialisations of structure adapted to different modes of life Some mammals became fleet of foot, and developed limbs specially adapted to enhance their powers of rapid movement They attained an early pre-eminence, and were able to grow to large dimensions in the slow-moving world at the dawn of the age of mammals Others developed limbs specially adapted for swift attack and habits of stealth, successfully to prey upon their defenceless relatives Others took to the water or the air, and acquired the modifications in structure and manners of life necessary to accommodate themselves to their new environments

Most of these groups attained the immediate success that often follows upon early specialisation but they also paid the inevitable penalty They became definitely committed to one particular kind of life, and in so doing they had sacrificed their primitive simplicity and plasticity of structure, and in great measure their adaptability to new conditions The retention of primitive characters, which so many writers upon biological subjects, and especially upon anthropology, assume to be a sign of degradation, is not really an indication of lowliness We should rather look upon specialisation of limbs and the narrowing of the manner of living to one particular groove as confessions of weakness, the renunciation of the wider life for one that is sharply circumscribed It may be asked why all these other non-Primate mammals, leading an active life, many of them in open competition with their fellows, did not develop brains as highly organised as those of the Primates The Ungulates and Carnivores, which most people who put such queries have in mind when they do so, develop large brains, although they are relatively very small in comparison with those of Primates of similar size There are many reasons for this Such creatures, even at the present day, always remain more or less under the influence of the sense of smell, and even though the visual, auditory, and tactile senses become well represented in the neopallium, these are secondary and relatively late modifications which have produced much less effect than the earlier usurpation of the dominant position by vision exerted in the Primates Nevertheless, visual and auditory centres and the interposed parietal area become well developed, especially in Carnivora like the Dog, Cat, Bear, and Seal—an anatomical fact which explains their high degree of educability But the growth of other cortical areas is subject to inevitable limitations in these creatures The specialisation of limbs, and this is peculiarly the case in Ungulates, to perform only a very limited range of more or less automatic movements, does away with all possibility of developing further either an area to preside over skilled movements or a controlling prefrontal 'area of attention,' the usefulness of which is restricted by the impossibility of performing many acts that call for such guidance Further progress along these lines was barred for all time by early specialisation of structure of the limbs, and hence these creatures lack one of the chief means which has led the Primate to the position of mental supremacy

The Primates at first were a small and humble folk, who led a quite unobtrusive and safe life in the branches of trees, taking small part in the fierce competition for size and supremacy that was being waged upon the earth beneath them by their Carnivorous, Ungulate, and other brethren But all the time they were cultivating that equable development of all their senses and limbs, and that special development of the more intellectually useful faculties of the mind which, in the long run, were to make them the progenitors of the dominant mammal—the mammal who was to obtain the supremacy over all others, while still retaining much of the primitive structure of limb that his competitors had sacrificed It is important, then, to keep in mind that the retention of primitive characters is often to be looked upon as a token that their possessor has not been compelled to turn aside from the straight path and adopt protective specialisations, but has been able to preserve some of his primitiveness and the plasticity associated with it, precisely because he has not succumbed or fallen away in the struggle for supremacy It is the wider triumph of the individual who specialises late, after benefiting by the all-round of experience of early life, over him who in youth becomes tied to one narrow calling

The Primates found in the branches of trees the asylum and protection necessary for the cultivation of brain and limbs during the period of their obscurity as an insignificant tribe, but when they became powerful enough to hold their own and wax great, both in size and power, they had maintained sufficient of their

primitive characters, and the plasticity that goes with them, to be able gradually to give up the arboreal mode of living and to re-establish themselves once more as dwellers on the solid earth, competent to hold their own against all comers

This principle extends not only to the Primate phylum itself, but to its different branches, and especially to Man

I should be inclined to look upon the Orang, the Chimpanzee, and the Gorilla not as ancestral forms of Man, but as the more unenterprising members of Man's family, who were not able to maintain the high level of cerebral development of the feeble-bodied human, but saved themselves from extinction by the acquisition of great strength and a certain degree of specialisation of structure The feebler Man was able to overcome his enemies and maintain himself in the struggle for existence by his nimbleness of wit and his superior adaptability to varying circumstances

In many respects Man retains more of the primitive characteristics, for example, in his hands, than his nearest Simian relatives, and in the supreme race of mankind many traits, such as abundance of hair, persist to suggest pithecoid affinities, which have been lost by the more specialised Negro and other races Those anthropologists who use the retention of primitive features in the Nordic European as an argument to exalt the Negro to equality with him are neglecting the clear teaching of Comparative Anatomy, that the persistence of primitive traits is often a sign of strength rather than of weakness This factor runs through the history of the whole animal kingdom [38] Man is the ultimate product of that line of ancestry which was never compelled to turn aside and adopt protective specialisations, either of structure or mode of life, which would be fatal to its plasticity and power of further development

Having now examined the nature of the factors that have made a Primate from an Insectivore and have transformed a Tarsioid Prosimian into an Ape, let us turn next to consider how Man himself was fashioned

It is this aspect of the problem of the origin of Man which has always excited chief interest and has been the subject of much speculation, as the addresses of my predecessors in this presidency bear ample witness

These discussions usually resolve themselves into the consideration of such questions as whether it was the growth of the brain, the acquisition of the power of speech, or the assumption of the erect attitude that came first and made the Ape into a human being The case for the erect attitude was ably put before the Association in the address delivered to this Section by Dr Munro in 1893 He argued that the liberation of the hands and the cultivation of their skill lay at the root of Man's mental supremacy In Professor Sollas' address to the Geological Society, to which I have had occasion to refer before in this address, the same view seems to be favoured, for we find the statement that 'the first change which started the Ape on the path towards Man was probably the assumption of the erect attitude ' But this expression of opinion follows immediately upon what Professor Sollas calls a 'confession of faith' stated in these terms 'My belief that the really fundamental change, underlying all the rest, was the increasing growth of the intellectual powers, and this I regard as an ultimate fact as difficult of explanation as any other ultimate fact, such as the origin of variations or even of life itself But, having made this admission, I shall not introduce it into any of the following speculations, which will be more in accordance with the prevailing philosophy of the day ' [39] But if the increasing growth of the intellectual powers underlies all the rest, why depose this factor in favour of the influence of the erect attitude merely out of deference to fashion? Moreover, if the nature of the intellect is 'an ultimate fact as difficult of explanation as any other fact,' it does not imply that we must give up all hope of understanding some at least of the factors that explain the increasing growth of the intellectual powers or the obvious physical manifestations of growth and specialisation in the cerebral cortex, which unquestionably make such increase of intellectual powers possible

If the erect attitude is to explain all, why did not the Gibbon become a Man in Miocene times? The whole of my argument has aimed at demonstrating that the steady growth and specialisation of the brain has been the fundamental

[38] Elliot Smith, 'The Brain in the Edentata,' *Trans Linn Soc*, 1899.

[39] *Proc Geol Soc*, xxxii, May 1910, p 1

factor in leading Man's ancestors step by step right upward from the lowly Insectivore status, nay, further, through every earlier phase in the evolution of mammals—for Man's brain represents the consummation of precisely those factors which throughout the vertebrata have brought their possessors to the crest of the wave of progress The external conditions of life have supplied the stimulus to this cerebral growth, as well as the sieve to strain off those individuals who do not adequately respond to the stimulus, and thus become 'unfit' to survive But such advances as the assumption of the erect attitude are brought about simply because the brain has made skilled movements of the hands possible yet once such a stage has been attained the very act of liberating the hands for the performance of more delicate movements opens the way for a further advance in brain development to make the most of the more favourable conditions and the greater potentialities of the hands

I have already referred to the common fallacy of supposing that the erect attitude is Man's distinctive prerogative, and of regarding the assumption of that position and mode of progression as the determining factor in the evolution of Man It is a fact beyond dispute that the divergent specialisation of the human limbs, one pair for progression, and the other for prehension and the more delicately adjusted skilled actions, has played a very large part in preparing the way for the emergence of the distinctively human characteristics, but it would be a fatal mistake unduly to magnify the influence of these developments The most primitive living Primate, the Spectral Tarsier, frequently assumes the erect attitude, and uses its hands for prehension rather than progression in many of its acts, and many other Lemurs, such as the Indrisinæ of Madagascar, can and do walk erect

In the remote Oligocene, a Catarrhine Ape, nearly akin to the ancestors of the Indian Sacred Monkey, *Semnopithecus*, became definitely specialised in structure in adaptation for the assumption of the erect attitude, and this type of early Anthropoid has persisted with relatively slight modifications in the Gibbon of the present day But if the earliest Gibbons were already able to walk upright, how is it, one might ask, that they did not begin to use their hands, thus freed from the work of progression on the earth, for skilled work, and at once, before men? The obvious reason is that the brain had not yet attained a sufficiently high stage of development to suggest appropriate occupation for these competent hands to do, to the exclusion of their function in climbing those areas of the neopallium, upon the integrity and normal functioning of which consciousness relies for its experience, based upon the memories of visual, auditory, tactile, and all other kinds of sensations, as well as of the recollection of what effects follow upon certain lines of action—the cortical areas which, as we know by processes of inference and exclusion, must be responsible for some such functions as these—are still small and insignificant in the Gibbon in comparison with those of the human brain, and in the first Gibbon-like Anthropoid ancestor of Man they were no doubt equally in their infancy If one considers, for instance, what a vast number of memories not only of sensations and relations between sensation factors, but also of conscious experience of the nature and results of innumerable acts, must be acquired before an animal can learn to anticipate what will happen as the direct effect of some action, before it can venture, for example, upon even so simple a purposive act as chipping a flint to produce a cutting edge, it must be evident that a vast neopallial storehouse for recording, and, so to speak, classifying, such experiences must be provided before the animal can begin to make the simplest inferences, compounded as these are of thousands of experiences, to make the conception of such an act possible

The Ape is tied down absolutely to his experience, and has only a very limited ability to anticipate the results even of relatively simple actions, because so large a proportion of his neopallium is under the direct influence of the senses, directly or indirectly, *i e*, is concerned with the memories of mere sensations

Psychologists tell us that 'so long as animals were absorbed in direct responses to the demands of their environment, their mental complexes were of a direct, primitive type, and stimulations issued into direct motor channels with relatively little possibility of ideational organisation' But 'as soon as a type of response developed which was indirect there was a complete change in the general mode of bodily and conscious organisation'[40] This distinction between the behaviour

[40] C H Judd, *Psychology*, General Introduction, 1907, p 253.

of Man and other mammals is obviously correlated with the great expansion of the temporo-parietal area, which is the fundamental distinctive feature of the human brain

In other Primates, even in the Anthropoid Apes, there is relatively only a small area intervening between the great visual, tactile, and auditory territories, and the fringing bands intimately associated with them, so that practically the whole of this part of the brain is under the direct influence of sensations that are constantly pouring in to keep the animal 'absorbed in direct responses to the demands of its environment', but the part of the temporo-parietal area which is not under such direct influences undergoes a steady increase in size as we ascend the Primate series, until in the Anthropoid Apes the three sensory territories are definitely being pushed asunder, the visual to the occipital pole, the auditory to the temporal region, and the sensory to the central The time eventually arrives when a sufficiently large area is formed where the functions of correlation of sensory images can go on undisturbed by the new stream of incoming impressions, and provide the physical mechanism for storing up records of the consequences of actions excited by the frontal areas, which must be the materials out of which the anticipation of what the result of any given action must be compounded

It may seem wildly speculative to speak in this manner of the way in which these great temporo-parietal and frontal areas perform their functions, when we are so profoundly ignorant of the precise nature of their working But they present the outstanding features of contrast in the brains of Men and Anthropoid Apes we know that these two areas show a progressive and unbroken increase in size in the series of Primates, with which we can associate the growing power of skill in manipulation, of intelligent action, and the faculty of learning to perform most complex movements, and the records of clinical medicine and psychiatry have given us some faint glimmerings of the way in which they perform their functions in Man

Thus there seems to be some justification for framing a definite working hypothesis to cover the factors that are known to us The temporo-parietal area is the storehouse for the memories of the states of consciousness compounded of visual, auditory, and tactile sensations, and its progressive growth and specialisation is the measure of the efficiency with which it performs these functions The central area is the storehouse for the memories of actions and the feelings associated with them The prefrontal area is concerned with attention and the orderly control of the psychical activities of the whole cortex, and its great expansion and high differentiation in Man may be taken to mean, among other things, that it correlates the actions of the central and temporo-parietal areas, and supplies the mechanism for recording the experience of the casual relationship between the states of consciousness, causes, and effects, with which the central and the temporo parietal areas respectively are more immediately concerned

I am aware that this is a rather clumsy and crude attempt at psychological analysis, but the idea I am striving to express is this that the Gibbon and the other Anthropoid Apes are 'strictly bound down to experience' and have not learned 'to anticipate to any extent what is going to happen,' because the parts of the brain, temporo parietal and prefrontal areas, which provide the mechanisms for correlating causes and effects and making such experience available to regulate conduct, are still small and relatively undifferentiated They are not yet sufficiently large to be removed far from the great sensory avenues along which a constant stream of traffic is surging and overflowing into these areas, compelling the latter to attune their activities to the immediate demands of the animal's environment

And so the Gibbon, not yet mentally endowed to anticipate the consequences of its acts and to do any great variety of useful things with its hands, developed its arms in size and cunning, and became the most expert gymnast the world has known Nor, again, when Man's nearer relatives, the Chimpanzee and the Gorilla, branched off from his ancestral line, were they any the more able to use their arms for the highest skilled work but they developed great strength, which enabled them to hold their own upon the ground and wax in size when pitted in competition with the animals of their African forest home In these specialisations of their limbs they lost something of the mechanisms that were

essential to Man, which his ancestors retained when those of the giant Anthropoids chose the lesser part of relying upon their strength rather than their intelligence

From the study of the brain in a series of Apes the fact emerges that in this progression there was taking place in the cerebral cortex a gradual extension and development of certain areas, which eventually made it possible for the Ape that achieved most in this way to make a fuller use of its erect attitude and employ its liberated hands and arms for a higher purpose than the rest of its tribe

Even in the lowliest Catarrhine Apes the cortical area which is set apart directly to receive visual impressions is as large and as highly developed as it ever will be, and perhaps we may assume, though our evidence is not yet so satisfactory, that the tactile and acoustic areas are not very much inferior, so far as the mere perception of touch and hearing is concerned, to those of Man But in the series of Primates we can detect fringes of cortex surrounding, perhaps growing out from, these great sensory areas, and others linking these fringing bands the one to the other, which show a progressive increase in size and complexity of structure, as we proceed from Prosimian to Platyrrhine, Platyrrhine to Catarrhine Ape, and through the series Gibbon, Chimpanzee, and Gorilla

The progressive increase in size of these areas presumably connotes the growth and perfecting of the apparatus for recording sensory impressions and the complex states of consciousness which are awakened by the blending of various impressions, visual, acoustic, tactile, and the rest, and the memories of similar or contrasted forms of consciousness that the individual may have experienced in the past

In Sir Edward Tylor's classical book on 'Anthropology' there is an admirable illustration of this in his comparison of the action of children and monkeys scrambling for nuts 'Knowing a nut by sight, or having an idea of a nut, means that there are grouped together in the child's mind memories of a number of past sensations, which have so become connected by experience that a particular form and colour, feel and weight, lead to the expectation of a particular flavour Of what here takes place in the child's mind we can judge, though by no means clearly, from what we know about our own thoughts and what others have told us about theirs What takes place in the monkeys' minds we can only guess by watching their actions, but these are so like the human as to be most readily explained by considering their brain-work also to be like the human, though less clear and perfect '

In Man there is relatively an enormous increase in the extent and degree of differentiation of the (temporo-parietal) region of the cerebral cortex which we must associate with this particular category of function Presumably this implies not only that there is provided in the human brain a much more extensive cortical area in which the records of experience can become imprinted, but also that this larger territory will be free from the disturbance of the constant traffic upon the main great sensory avenues, such as is inevitable in brains in which the temporo parietal area is little more than a narrow strip sandwiched in between the great sensory areas, and liable to be flooded and overwhelmed by the sensory impressions streaming into the cortex through them In the Apes even the most highly endowed Anthropoids, the conduct of the animal is attuned to the sensory impressions of the moment (modified in some degree only by the experience of the past), because the cerebral cortex is so flooded with impressions from the outside world

But the time comes in the gradual development of the brain, along the lines we see exemplified in the series of Apes, when those cortical areas not immediately concerned with the reception of sensory impressions become so large and so stored with the fruits of experience that they come to exercise an influence upon conduct more potent than that of direct sensory stimulation Undisturbed by the stream of impressions constantly pouring into the sensorium, they provide a mechanism for recording to an almost unlimited extent not only the mere visual, tactile, and other qualities of objects, and the states of consciousness each awakens, but also the recollection of acts and their consequences, so that Man is endowed with such a wealth of experience of the consequences of certain lines of action that he is able to foresee the results of his behaviour and modify it accordingly

In comparison with the Apes, Man has an enormously enhanced faculty of profiting by experience, and of controlling the impulse to respond to every sensory stimulus in his environment by recalling the consequences of such responses on previous occasions We may correlate these contrasts in behaviour with the striking differences in the cerebral cortex In the Ape the activity of the greater part of the neopallium is to a large extent controlled by impressions streaming into its various parts from one or other of the sense organs or other sensitive structures in the body In the course of evolution of the human brain there is added to this cortex of Man's Simian progenitor a mass of tissue, roughly, about five hundred cubic centimetres, bigger than the whole of the Gorilla's brain, and as the sensory areas of the human brain are practically equal to those of the Gorilla, all this enormous increase goes to swell the dimensions of those parts of the cortex which do not receive sensory impressions directly These neopallial areas are at least six times as large in the human brain as they are in the Gorilla's To put these facts into a slightly different form, in the Simian brain the sensory areas predominate, and the behaviour of the animal is to be looked upon as the response to the immediate sensory impressions of the moment in the human brain the great association areas have grown far beyond the dimensions of the sensory areas, and experience, the effects of education, and knowledge assume the dominant role in influencing conduct

In the series of Primates it is found that the size of the cortical area controlling skilled movements increases as we ascend the scale, and the variety, complexity, and skilled nature of the movements become markedly increased The extent to which the Anthropoid Apes can be trained to remember and perform the most complex actions must be familiar to everyone who has visited the modern 'music hall' or travelling menagerie

Thus it happens when the brain reaches the stage in its evolution to impel its possessor to attempt complex purposive acts directed toward the accomplishment of some intelligent aim, the hand and arm are not only ready and free from the duty of progression, but they already have attained in great measure the skill and the cunning to perform what the intelligent will requires of them

What more favourable conditions could be imagined than these for the forces of natural selection to seize hold of, to fix and establish more definitely the erect attitude, to make the hand a more delicate and exact instrument capable of performing infinitely more complex and varied skilled actions, to make the leg a more efficient support, and thereby simultaneously to give still more freedom to the all important hand, while the growing brain is all the time becoming more richly endowed with the potentialities of the conscious memory, reciprocally stimulating and being stimulated by the motor centres, which, by directing the performance of new manœuvres, add to the storehouse of consciousness new elements of experience of cause and effect?

The erect attitude, infinitely more ancient than Man himself, is not the real cause of man's emergence from the Simian stage but it is one of the factors made use of by the expanding brain as a prop still further to extend its growing dominion, and by fixing and establishing in a more decided way this erectness it liberates the hand to become the chief instrument of Man's further progress

In learning to execute movements of a degree of delicacy and precision to which no Ape could ever attain, and which the primitive Ape man could only attempt once his arm was completely emancipated from the necessity of being an instrument of progression, that cortical area which seemed to serve for the phenomena of attention became enhanced in importance Hence the prefrontal region, where the activities of the cortex as a whole are, as it were, focussed and regulated, began to grow until eventually it became the most distinctive characteristic of the human brain, gradually filling out the front of the cranium and producing the distinctively human forehead In the diminutive prefrontal area of *Pithecanthropus*,[41] and, to a less marked degree, Neanderthal man,[42], we see illustrations of lower human types, bearing the impress of their lowly state in receding foreheads and great brow ridges However large the brain may be

[41] Eug Dubois, 'Remarks upon the Brain-cast of Pithecanthropus,' *Proc. Fourth Internat. Cong Zool*, August 1898, published Camb., 1899, p. 81.

[42] Boule and Anthony, 'L'encéphale de l'homme fossile de la Chapelle-aux-Saints,' *L'Anthropologie*, tome xxii., No. 2, 1911, p. 50.

in *Homo primigenius*, his small prefrontal region, if we accept Boule and Anthony's statements, is sufficient evidence of his lowly stage of intelligence and reason for his failure in the competition with the rest of mankind

Once the Simian ancestor of Man began to anticipate the consequences of his acts and put this knowledge and the growing appreciation of the powers of his hands to useful purpose, for using weapons, or even making them, the erect attitude would become a regular habit, so as to emancipate the hands entirely for their new duties The realisation of his ability to defend himself upon the ground, once he had learned the use of sticks and stones as implements, would naturally have led the intelligent Ape to forsake the narrow life of the forest and roam at large in search of more abundant and attractive food and variety of scene Like most creatures who live in the open, the adoption of social habits is one of the surest means of protection, for the eyes and ears of each individual thus become the servants of the whole community, giving warning of danger, and thus adding to the safety of the herd The development of the legs then became a necessary condition of survival for warnings of danger to animals living in the open are useless without fleetness of foot to escape or skill of arm to ward off the threatened danger Thus we have come to realise the steps by which a growing brain makes it possible and desirable for the most intelligent of the Apes to forsake the purely arboreal life and seek a wider sphere of activity upon the earth they emerged from their original forest home, and in troops invaded the open country, led on no doubt by the search for a more plentiful supply or a more appetising variety of food Such an existence, demanding an ever-increasing skill to use implements of defence and to specialise the arms in using them, and at the same time fleeter limbs, better adapted for progression on the earth, would rapidly transform the limbs and specialise them each for its separate functions

Thus it is easy to conceive how it came to happen, once the evolution of the brain made it possible for the Ape to appreciate its ability to perform and anticipate the results of skilled actions, that he at once began to avail himself of the larger life that was opened before him He already possessed the skill to use his hands, and this became emphasised with their added usefulness and value to their possessor, the more efficient brain, and increased delicacy of the hands themselves, once they ceased to be mere prehensile instruments And the emancipation of the hands from progression threw the whole responsibility upon the legs, which became more efficient for their purpose as supports once they lost their prehensile powers and became elongated and specialised for rapid progression Thus the erect attitude became stereotyped and fixed and the limbs specialised, and these upright Simians emerged from their ancestral forests in societies, armed with sticks and stones, and with the rudiments of all the powers that eventually enabled them to conquer the world The greater exposure to danger which these more adventurous spirits encountered once they emerged in the open, and the constant struggles these first semi human creatures must have had in encounters with definite enemies, no less than with the forces of Nature, provided the factors which rapidly weeded out those unfitted for the new conditions, and by natural selection made real Men of the survivors

The growth in intelligence and in the powers of discrimination no doubt led to the dawning of a definite æsthetic sense, which, operating through sexual selection, brought about a gradual refinement of the features, added grace to the general build of the body, and demolished the greater part of its hairy covering It also intensified the sexual distinctions, especially by developing in the female localised deposits of fatty tissue, not found in the Apes, which produced profound alterations in the general form of the body

To one who considers what precisely it means to fix the attention and attempt the performance of some delicately adjusted and precise action it must be evident that one hand only can be usefully employed in executing the consciously skilled part in any given movement The other hand, like the rest of the muscles of the whole body, can be only auxiliary to it, assisting, under the influence of attention, either passively or actively, in steadying the body or helping the dominant hand Moreover, it is clear that if one hand is constantly employed for doing the more skilled work, it will learn to perform it more precisely and more successfully than either would if both were trained, in spite of what ambidextral enthusiasts may say Hence it happened that when Nature was fashioning Man

the forces of natural selection made one hand more apt to perform skilled movements than the other Why precisely it was the right hand that was chosen in the majority of mankind we do not know, though scores of anatomists and others are ready with explanations But probably some slight mechanical advantage in the circumstances of the limb, or perhaps even some factor affecting the motor area of the left side of the brain that controls its movements, may have inclined the balance in favour of the right arm, and the forces of heredity have continued to perpetuate a tendency long ago imprinted in Man's structure when first he became human

The fact that a certain proportion of mankind is left-handed, and that such a tendency is transmitted to some only of the descendants of a left-handed person, might perhaps suggest that one half of mankind was originally left-handed and the other right-handed, and that the former condition was recessive in the Mendelian sense, or that some infinitesimal advantage may have accrued to the right-handed part of the original community, which in time of stress spared them in preference to left-handed individuals, but the whole problem of why right-handedness should be much more common than left handedness is still quite obscure The superiority of one hand is as old as mankind, and is one of the factors incidental to the evolution of Man

It is easily comprehensible why one hand should become more expert than the other, as I have attempted to show, and the fact remains that it is the right hand, controlled by the left cerebral hemisphere, which is specially favoured in this respect This heightened educability of the (left) motor centre (for the right hand) has an important influence upon the adjoining areas of the left motor cortex When the Ape-Man attained a sufficient degree of intelligence to wish to communicate with his fellows other than by mere instinctive emotional cries and grimaces, such as all social groups of animals employ, the more cunning right hand would naturally play an important part in such gestures and signs, and, although the muscles of both sides of the face would be called into action in such movements of the features as were intended to convey information to another (and not merely to express the personal feelings of the individual), such bilateral movements would certainly be controlled by the left side of the brain, because it was already more highly educated

Up to this stage the means of communication with other individuals was practically confined to signs and gestures, controlled by the left brain of the signaller and appreciated by the visual apparatus of the receiver and no doubt a special bond was established between the visual areas, in which the memories of such signs and their meanings were recorded, and the area in which the memories of the particular movements of arms and face were stored and as the latter were controlled in the left hemisphere, the bond between the visuo-psychic and arm head motor centres would be specially intimate in the left cerebral hemisphere

The increased control acquired by the left motor centres (over the right hand and both sides of the face) also extended to the left centres that regulate the muscles of the tongue, palate, and larynx, and the skill that the primitive Ape-Man had acquired to perform delicately adjusted actions with the right hand and face naturally became extended to include these other muscles, the movements of which are regulated by the adjoining cortical area, and are also used to aid in expressing the ideas conveyed by the movements of the hand and face Then he learned to make a much greater variety of sounds than he has inherited from his Gorilla like and Gibbon-like ancestors To the memories of the sounds of other animals and of the noises that occur in Nature, which had already become stored up in the sensorium of Apes, the primitive Ape-Man added a collection of records of the expressive sounds deliberately emitted by his fellows; and in course of time the consciousness of these sounds was recorded, along with the memories of his gestures and grimaces, associating each with some meaning, which became a new way of communicating with his fellows

The perfection of the cortical mechanism for appreciating sounds and detecting a very wide range of qualities is associated in the human brain with a remarkable growth and differentiation of the auditory area of the cortex [43] As intercommunication between members of a social group became a matter of

[43] Brodmann, *op cit*, p 144

vital importance to the individuals composing it, this acuity in recognising sounds of different pitch, tone, and timbre, and in detecting their precise emotional significance, would grow *pari passu* with the acquisition of speech.

From the time the early Primate ancestor of Man took to an arboreal mode of life, the sense of hearing has always been keen and especially well-represented, though not to the degree that vision is, in the neopallium; but this normal acuity of the Primate hearing became enormously heightened, or rather, attuned to perceive a much greater variety of sounds, when it came to be the chief means of communication between Men.

It must be quite evident that the first essential condition of speech must be the evolution of an area (usually in the left brain) in which there can be added to the vast collection of visual, auditory, tactile, and other complex states of consciousness already stored in it, not only the memories of the visual impressions of gestures and their meanings, but also of sounds and their associated ideas—that is, the state of consciousness which each particular sound awakens, through being linked up in memory with the auditory sensation; and the second essential must be a motor cortex sufficiently skilled to produce similar gestures, grimaces, and sounds. But just as a child must learn the meaning of words long before he attempts to reproduce the sounds himself, so in the dawn of human existence the Ape-Man educated his acoustic cortex to associate definite meanings with the sounds that occurred in Nature around him, and no doubt learned to imitate them before he began to invent new sounds to express new meanings, or to imitate those emitted by his fellow-Men. If it was the precocious high development of the sense of sight that started the Primates on their career, the high development of the cortical mechanism for discriminating sounds played a great part in making Man from an Ape. I think that most anthropologists who approach the study of speech from the physical or biological side have concentrated too much attention upon the supposed motor centres, and not enough on the great temporo-parietal areas, upon the education of which the faculty of speech, as Pierre Marie is rightly insisting, so largely depends. In other words, our Simian ancestor must have had something to say before he attempted to find means of expressing it.

I do not propose to discuss the tremendous impetus that the invention of speech must have given to human progress and intellectual development, in enabling the knowledge acquired by each individual to become the property of the community and be handed on to future generations, as well as by supplying in words the very symbols and the indispensable elements of the higher mental processes. This theme has been frequently discussed by many great thinkers; it has been expounded by several of my predecessors in this chair, and its influence pictured much more graphically and eloquently than I am capable of doing. For as Huxley has well said: Man 'alone possesses the marvellous endowment of intelligible and rational speech, whereby, in the secular period of his existence, he has slowly accumulated and organised the experience which is almost wholly lost with the cessation of life in other animals; so that now he stands raised upon it as on a mountain top, far above the level of his humble fellows, and transfigured from his grosser nature by reflecting here and there a ray from the infinite source of truth.'[44]

We are apt to forget the immensity of the heritage that has come down to us from former generations of Men, until we begin dimly to realise that for the vast majority of mankind almost the sum-total of their mental activities consists of imitation or acquiring and using the common stock of knowledge. For this accumulation of knowledge and its transmission to our generation we are almost wholly indebted to the use of speech. In our forgetfulness of these facts we marvel at the apparent dulness of early Man in being content to use the most roughly chipped flints for many thousands of years before he learned to polish them, and eventually to employ materials better suited for the manufacture of implements and weapons. But is the more highly cultured and civilised population of our own day so much more fertile of ideas? Is it not the fact that no really new idea ever enters the mind of the vast majority of mankind, and even much that seems new is really compounded of the knowledge gained by others? When we consider how slowly and laboriously primitive Man acquired new ideas,

[44] Quoted by Sollas, *op. cit.*, p. lxxxvii.

and how such ideas—even those which seem childishly simple and obvious to us—were treasured as priceless possessions and handed on from tribe to tribe, what becomes of the current theories of independent evolution of customs and culture? What room is there for hypotheses of 'similar workings of the human mind leading to the development of similar inventions'? Really original ideas were far too rare in the youth, and in fact also in the full flush of adult age, of mankind, for us seriously to consider the possibility that merely similar circumstances would tend to call forth similar ideas. This brings us back to the place from which we started. The very essence of intelligence is the uncertainty of the response it gives to 'similar circumstances', the blind forces of environment working in two organisms may lead to similar results, but who can predict the final issue when intelligence interferes?

The modern problems of anthropology that we have to solve, those which relate to Man and his inventions since the time of his world-wide distribution and differentiation into distinct races, are not so much questions of independent evolution, but rather those concerning the migrations, the intermixtures and the blendings of different races and cultures. The hypothesis of the 'fundamental similarity of the working of the human mind' is no more potent to explain the identity of customs in widely different parts of the world, the distribution of megalithic monuments, or the first appearance of metals in America, than it is to destroy our belief that one man, and one only, originally conceived the idea of the mechanical use to which steam could be applied, or that the electric battery was not independently evolved in each of the countries where it is now in use.

In these discursive remarks I have attempted to deal with old problems in the light of newly-acquired evidence, to emphasise the undoubted fact that the evolution of the Primates and the emergence of the distinctively human type of intelligence are to be explained primarily by a steady growth and specialisation of certain parts of the brain, that such a development could have occurred only in the Mammalia, because they are the only plastic class of animals with a true organ of intelligence, that an arboreal mode of life started Man's ancestors on the way to pre-eminence, for it gave them the agility, and the specialisation of the higher parts of the brain incidental to such a life gave them the seeing eye, and in course of time also the understanding ear, and that all the rest followed in the train of this high development of vision working on a brain which controlled ever-increasingly agile limbs.

If I have made these general principles clear, however clumsily set forth, and with whatever crudities of psychological statement they may be marred, I shall feel that I have not laboured in vain.

The following Papers were then read:—

1. *The Disappearance of Useful Arts.*[1] *By* W. H. R. Rivers, *M.D., F.R.S.*

In many parts of Oceania there is evidence that objects so useful as the canoe, pottery, and the bow and arrow have once been present in places where they are now unknown or exist only in degenerate form. It is often impossible to find adequate motives for this loss in such obvious factors as lack of raw material or unsuitability to a new environment. Social factors not at once obvious, and even magical or religious beliefs and practices, have to be brought in to explain the loss.

The limitation of the manufacture of useful objects to small bodies of craftsmen liable to be destroyed through disease or war has probably been an important factor, but this alone would not have been sufficient if the religious character of the craft had not prevented other members of the community from following it when the craftsmen disappeared.

Some of the widely accepted theories of anthropology depend on the assumption that useful arts would never be allowed to lapse. This assumption, which rests on the application of our utilitarian standards of conduct to cultures widely

[1] Published in full in *Festschrift Tillagnad Edvard Westermarck.* Helsingfors, 1912, pp. 109-130.

different from our own, has been shown to be without justification. If islanders can lose the canoe, of what elements of culture can we say that they could never be lost?

---

2. *'Conventionalism' in Primitive Art.*
By W. H. R. RIVERS, *M.D., F.R.S.*

The opinion, almost regarded as a truism in this country, that the geometrical patterns of primitive art have arisen through the conventionalisation of natural objects, is by no means universally accepted. Boas and others in America hold that the movement may take place in the opposite direction, features of a conventional design suggesting ideas which find their expression in naturalistic representations. The German historical school believe that designs often regarded as stages in a process of conventionalisation are merely examples of the mixture of motives belonging to different peoples, and it is believed that a transition is as likely to take one direction as the other. Others, again, see a sufficient explanation of the changes which occur in purely technical considerations.

In Polynesia and Melanesia we can be confident that the general direction of change is from naturalistic representations to geometrical patterns. Series of objects can be found with intermediate links wholly inexplicable on any other hypothesis. Nevertheless, the various psychological factors implied by the term 'conventionalisation' do not furnish a complete explanation. Such factors as economy of labour or inexactness in copying would account for simplification or for degeneration into all kinds of meaningless and irregular forms. They cannot account for the coming into being of definite geometrical patterns, sometimes even more complicated than the objects from which they have been derived. Similarly, purely technical factors are insufficient. The nature of material or implements may help to explain why a process of change should be in the direction of straight or curved lines, and the nature of the surface to be decorated may account in some measure for the degree of complexity of the final pattern. Such motives, however, are insufficient to explain why, for instance, the human figure should become in one place a lozenge and in another a set of concentric circles or even a spiral, why in one place it is the face or eye and in another the limbs which persist in geometrical form. The direction taken by the process of conventionalisation cannot be explained purely by psychological or technological factors, but in many cases at least the motive must be sought in the interaction of peoples possessing different forms of artistic expression.

Thus, the art of the Banks Islands in Melanesia is most naturally to be explained as the result of the interaction between two peoples: one coming from elsewhere, whose art was devoted to the expression of human and animal forms; the other an aboriginal population, whose designs consisted chiefly of simple rectilinear patterns. The transition from the representation of a man to such a figure as the lozenge is to be explained by the greater persistence of the aboriginal form of expression as the art introduced by the immigrants was transmitted from person to person, and from generation to generation. Similarly, the transition from the frigate-bird to the scroll pattern of the Massim is to be explained by the mixture of a people to whom the frigate-bird was a predominant object of interest with one whose geometrical art had taken the spiral and other curvilinear forms.

Conventionalisation, as a term for changes due to the saving of labour, inexactitude in copying, and other similar factors, is a process which has played a large part in the history of art, but for the special directions taken by the process we must look to factors arising out of the blending of cultures.

---

3. *Notes on the Magic Drum of the Northern Races.*
By DAVID MACRITCHIE.

In the shamanistic ceremonies of the races occupying the northern parts of the Eurasian continent and of the Japan Islands, the sacred drum has long been used as a medium enabling the priest to place himself *en rapport* with the spirit world. By this means he can not only divine the future, but he can also ascertain synchronous events occurring in foreign countries. He can also, by its aid,

forecast the measure of success attending the day's hunting or other business, heal the sick, afflict healthy people with disease, and cause death In Swedish Lapland the magic drum fell under the ban of the law in 1671, when several Lapp magicians were apprehended and their drums burnt The sacred drum of the Samoyeds is described by Gourdon in 1614 as 'a great tabor made with a wolf's skin,' and he mentions that a hare's foot was used as a drumstick The Lapp drum is struck with a specially made hammer Although the Lapp drum is now only seen in museums, the magic drum of the Samoyeds is still in use The North American and Greenland Eskimo give a prominent place to the drum, but it seems to be chiefly used by them as a musical instrument

---

4 *Recent Excavations at Sakkara, with special reference to the Tomb of Hesy* *By* J E QUIBELL

About 400 tombs of the Second and Third Dynasties have been examined during the last two winters They are mastabas of crude brick, with stairway shafts, of small burial chambers in which the body lay in a contracted position All except the poorest had been robbed in antiquity In one only, that of Hesy, were paintings found

The wooden panels of Hesy were placed in the Boulac Museum by Mariette more than forty years ago, but no description of the tomb was published, and its site had been lost This year it was refound, and an hitherto unobserved wall, forming a part of it, has been disclosed This wall is over 30 metres long, and is covered with paintings of a markedly different design from any hitherto known The deceased is represented seated under a tent, while before him, on a large mat, are laid trays of wood containing his funeral furniture There are in this scene no hieroglyphs, no human figures, nothing resembling the other Old Kingdom tombs A clay sealing dates the monument to the reign of Nefer-Kha, the builder of the Step Pyramid (Third Dynasty)

---

5 *Sarawak Music* *By* Dr C S MYERS

FRIDAY, SEPTEMBER 6

The following Papers and Report were read —

1 *The Suprasylvian Operculum in the Brains of Primates, with special reference to its Condition in Man* *By* Professor RAOUL ANTHONY *and* Dr A S DE SANTA MARIA

To arrive at any proper conception of the morphological significance of the neopallial swelling which forms the upper lip of the Sylvian complex in the human brain, it is indispensable that our interpretation should be based upon the new conceptions of telencephalic topography set forth mainly in the works of Professor G Elliot Smith, which our own recent researches [1] have in some measure helped more precisely to define in respect of certain points

The suprasylvian operculum of the Primates is essentially a part of the cortical territory which we have called 'peripheral' From the morphological point of view it can be considered as the result of an expansion of the cortex at the place where the change of thickness in the wall of the cerebral hemisphere occurs as the result of the presence of the central grey nuclei (*corpus striatum*)

Consisting in the human brain of arcuate convolutions, each possessing an axial sulcus, and separated the one from the other by more or less definite

[1] *C R Acad des Sciences Paris*, 1911, *Rev. Scientifique*, 1911, *Rev. Anthropologique*, April and July 1912.

incisions, it presents for our consideration the following esential parts, some of which do not exist at all, and others are merely outlined, in the other Primates —

1 *Suprasylvian Operculum* —Present in all Primates with definitely convoluted brains, with the solitary exception of *Chiromys*, it is due to an expansion of the cortex situated above the suprasylvian sulcus, which made its appearance long before any opercular formation began [2]

As the result of influences causally related to the flexion of the cerebral hemisphere, which reaches its maximum in the human brain, the suprasylvian sulcus undergoes a bending some distance behind the pseudosylvian sulcus Thus it comes to pass that the suprasylvian operculum is subdivided into two parts (*a*) a direct part which remains superficial (the Rolandic operculum of authors), and (*b*) a reflected part which, becoming submerged, does not enter into the constitution of the superior lip of the sylvian complex (anterior part of the deep temporo-parietal annectant gyrus)

2 *Opercula of the Gyrus Reuniens* — The gyrus reuniens in the lemurs, as it is in the dog family, is altogether superficial In the anthropoid apes its posterior part (the middle insula of Holl) alone is operculated In man only is its anterior part (the anterior insula of Marchand) operculated, although in certain very precious individual specimens of gorilla—and chimpanzee—brains we have been able to find the commencement of similar operculation

The operculum of the gyrus reuniens consists, in man, of two parts (*a*) a posterior part, which is also found in the anthropoid apes (the Prerolandic operculum of authors), and (*b*) an anterior part characteristic of the human type (frontal operculum or *cap de Broca*)

3 *Holoperipheral Operculum* —Situated altogether behind, this operculum represents the operculation of a part of the peripheral territory itself Its presence is the direct result of the bending of the suprasylvian sulcus (Postrolandic operculum of authors)

---

2 *The Brain of the La Quina Fossil Man*

By Professor RAOUL ANTHONY

The brain of the fossil man from La Quina, whose remains were discovered by Dr Henri Martin on September 18, 1911, closely resembles those of Neander thal, Gibraltar, and La Chapelle-aux-Saints In all its dimensions, however, it is smaller than the Chapelle aux-Saints brain, which seems to be due to a difference in sex, the latter being a man's, whereas the La Quina bones are a woman's remains

Like the brain of the Chapelle man the Quina brain is distinguished by its great length and flatness, but does not attain the same breadth as the former The reduction of the anterior cerebral region is most marked As in the Chapelle and Gibraltar brains the posterior parts of the cerebral hemispheres markedly overhang the cerebellum, and there is a noteworthy separation between the lateral lobes of the cerebellum

The measurements made to estimate the relative development of the different lobes of the cerebral hemispheres furnished figures practically identical with those obtained from the Chapelle brain The frontal lobe in particular presents in relation to the other lobes a development intermediate to that found among the anthropoid apes (Simiidæ) on the one hand and modern men on the other (Frontal index Simiidæ = 32 20 La Quina = 35 70 La Chapelle = 35 75 Modern Men = 43 30)

The neopallial topography appears to have been equally similar to that of the man of La Chapelle Upon the cast one can distinguish the traces of a broad and large frontal operculum or *cap de Broca*, and in the occipital region the traces of a very well-developed *sulcus lunatus*

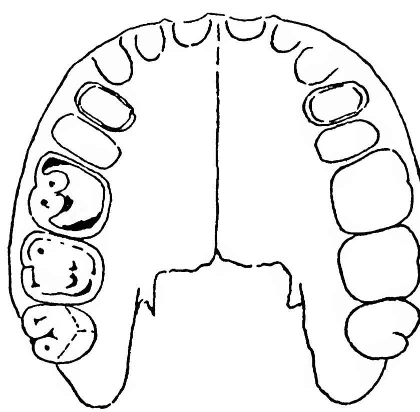
[2] For the identification of the suprasylvian sulcus among the Primates, see G Elliot Smith, *Descriptive and Illustrated Catalogue of the Physiological Series of Comparative Anatomy contained in the Museum of the Royal College of Surgeons of England*, vol ii, second edition, 1902, and 'On the Morphology of the Brain in the Mammalia, with Special Reference to that of the Lemurs, Recent and Extinct,' *Transactions of the Linnean Society of London*, second series, Zoology, vol viii, part 10, 432, and our own memoir, 1912.

Taking all their features into consideration the brains of the fossil human beings of La Quina and La Chapelle appear to come nearer to the brains of the anthropoid apes than any other known human brains.

3 *The Brain of the Gibraltar Fossil Woman* *By* Professor ARTHUR KEITH, *M D*, *F R C S*

4 *Description of a Human Jaw of Palæolithic Antiquity from Kent's Cavern, Torquay* *By* W L H DUCKWORTH, *M D.*, *Sc D*

On the occasion of the meeting of the British Association for the Advancement of Science at Dundee, in September 1867, the Third Report was received from the Committee appointed to supervise the exploration of Kent's Cavern, Torquay The Report announced the discovery (on January 3, 1867) of a fragmentary human upper jaw, embedded in the granular stalagmite floor, 20 inches



Human jaw from Kent's Cavern, Torquay. No. 1930. Only the right half was preserved. The left half in the figure is a reversed outline of the right half. The tracing is about five-sixths of the natural size.

thick This jaw was the most ancient representative of the human skeleton so far discovered in the cavern Its associations indicated an antiquity corresponding to that of the extinct cave animals At the time (1867) its value in evidence was extremely great Nothing of the kind was subsequently met with either in or beneath the granular stalagmite (Pengelly, 1884) Forty-five years have passed, and (so far as is known) no detailed account of the specimen has ever been published For this reason I have endeavoured to provide a fuller description than is available at present · The Council of the Natural History Society of Torquay most courteously lent me the specimen for the purposes of this study It is hoped that the Council will be able to publish the report in their Journal before very long

The fragment (No 1930, Case 7, of the Torquay Collection from Kent's Cavern) is, as already said, a human upper jaw of which a good deal has been destroyed. The remaining parts include the alveolar margin and palatine process, as well as the four teeth mentioned above They are the first premolar and the three molars (of the right side) A rough crystalline deposit encrusts the bone, but the outline is quite distinct and the much-worn crowns of the teeth are

exposed Their form and appearance may be better understood by reference to the figure, which represents the complete palate The right half is a tracing from the actual specimen, and this has been reversed and re-drawn to complete the rest of the outline

The most important points are (*a*) the transverse width at the level of the premolar teeth, and (*b*) the dimensions of the molar crowns

In regard to these points, the Kent's Cavern specimen comes fairly into line with those examples of human jaws and teeth to which palæolithic antiquity is definitely assigned On the whole, the resemblances to the fragmentary upper jaw of the Spy specimen (No 1) are the closest But the Kent's Cavern teeth have distinctly larger crowns than the Spy teeth, which are not remarkable in this respect

In the Kent's Cavern specimen the curious fusion of the molar roots which characterises the molar teeth from Jersey (S Brélade's Bay), and also from Krapina, is not present Neither is it found in the teeth of the jaw from Spy Its absence, therefore, does not exclude the Kent's Cavern jaw from the ranks of such as can claim an origin in the palæolithic period, to the later division of which it is to be referred

In submitting this brief note I wish to draw attention to the fact that Kent's Cavern is not yet exhausted, that a new passage or gallery was discovered there during the month of June 1912, and that valuable material is constantly coming to light It is greatly to be desired that definite supervision of the cavern should be instituted

5 *Discussion on Scottish Folklore*

(i) *The Study of Customs connected with the Calendar in Scotland* *By* W CROOKE, *B A*

This paper suggested some considerations on the question of the influence of race on Scottish custom and belief Attention was called to the importance of the study of Calendar Customs in Scotland, many of which seem to be survivals of the primitive method of reckoning time by seasons, not by solar or lunar changes It was suggested that traces of this primitive mode of reckoning may be found in the dates of hiring-fairs for domestic and agricultural servants An appeal was made for help by readers towards the completion of two schemes which have been undertaken by the Folklore Society– a new edition of Brand's 'Observations on Popular Antiquities,' and the series of extracts from published sources, several volumes of which have already been published under the title of 'County Folklore'

(ii) *Folklore as an Element of History* *By* E S HARTLAND

The formal history, whether of a country at large or of a county, tells us little or nothing of the life of the bulk of the people It is concerned with political transactions, with the State religion, or with the succession of ruling families These matters, important as they may be, affect the life of the people comparatively little Folklore, on the other hand, investigates the sayings and doings of the people as distinguished from the ruling classes, with a view to ascertain their modes of thought and the practices handed down from remote and unknown ancestors It thus provides an element often overlooked, but essential if we would understand the evolution of our civilisation The north-eastern counties of Scotland were for ages the battle-ground of races whose descendants form the present population A collection of its folklore should therefore present many interesting features having an important bearing on the history of the country

(iii) *Fairy and other Folk-Beliefs in the Highlands and Lowlands.* *By* Canon J. A MACCULLOCH, *D D*

There is great ultimate similarity of folk-lore everywhere Examples of this from Scotland are —(*a*) Charms (Highland, Etruscan, Babylonian), (*b*) water-

monsters (Highland, Lowland, Teutonic, Australian), (c) beliefs of fisher-folk (Hebrides, East Coast of Scotland)

Any attempt to prove particular ethnic influences is a matter of difficulty, especially in Scotland, where (a) races have mingled, and (b) civilisation and religion have altered so many old beliefs

Yet there is a possibility of arriving at some definite results by a careful comparison of folk-beliefs with earlier race-traditions, and older Pagan beliefs where these are available, and with the characteristics of the folk themselves Illustrations of this may be drawn from the *fairy-belief* as found in three districts of Scotland—the West Highlands, the Lowlands, and the northern districts and islands, representing respectively and in the main, Celtic, Teutonic, and Scandinavian cultures Similarity of general beliefs in fairies and in kindred beings prevails in all parts of the world The main differences must be looked for rather in the setting and in the characteristics of the fairies themselves than in the actions related of them, &c —

1 Highland fairies connection with Irish fairies and with earlier divinities, the Tuatha Dé Danaan, greater romanticism and imagination

2 Lowland fairies homely, rough, boisterous humour, connection with Teutonic elves

3 Northern names and certain characteristics show connection with the fairy-folk of Scandinavia

While in both Highland and Lowland groups there is a similarity of occupation ascribed to fairies, yet more particularly in the Highlands certain things reflect the life of the folk quite accurately.

In the Highlands the belief is much more *animistic* than in the Lowlands Connection of fairies and the dead In the Lowlands the belief is mixed up with witchcraft

Different aspects of Highland and Lowland tales about fairies

The fairy-belief is wrapped up with the life of the folk in the Highlands more than in the Lowlands, and is much more a living belief

Other branches of folk-belief show similar results —

1 The old Celtic civilisation and the heroic sagas Influence on thought and life of the people, and on *Marchen* Lack of this in the Lowlands Traces in place-names

2 Characteristic names given to archæological remains in both regions

Greater vitality and complexity of folk-belief is shown in the Highland regions than in the Lowlands

As examples of beliefs still active there may be cited —The evil eye, second sight, and shape-shifting

There is an urgent need of collecting and preserving the details of folk-belief

(iv) *Ethnological Traces in Scottish Folklore*
By J W Brodie-Innes

Of the original inhabitants of Scotland before the first coming of the Celts practically nothing is known Picts, Fomors, Cave men, River drift men, all is obscure—but here and there old and unidentified folk-tales may some day give a clue There were various migrations of Celts, Iberi, and Celtiberians, and if the Tuatha de Danaan could be identified with the Danai of Homer, it might account for similarities with Greek legends And if the Iberi were the same as Ibri, and thus connected with Hebrews, and with the Ibah-Erri, the men of the river, or the Crossers-over, the parallelism between Gaelic and Old Testament stories would have a special interest It may be possible in some such way to analyse the blend of the old Celtic folk-tales which are much the same in Ireland and in the Western Hebrides These cover a wide range, from the Ossianic myths and Bardic tales, which are epic, through such stories as those of Finvara and the Riders of the Sidh, which are chivalrous and romantic, and akin to the Arthurian, to the Fairy-Faith and the stories of Elementals, and to simple nature myths On to these again was grafted the Scandinavian cycle of legends, brought by the Norse invaders and

conquerors These may sometimes be distinguished by comparing the folk-tales of the West of Ireland with the same stories as told in the Highlands Both are to be met in the Isle of Skye, and sometimes a blend of the two The contrast is marked in the way the Water Elementals are regarded—to the pure Celt the people of the waters are gentle, kindly, and very friendly, but to the Norsemen, fierce, cruel, and revengeful The legend on which Matthew Arnold's 'Forsaken Merman,' common to both the Western Gael and the Norseman, is based, is a good example of a poetic blending of both Extraneous stories sometimes crop up in a Celtic dress, as that of the fairy flag of Dunvegan, which bears manifest traces of a Saracen origin, but is ascribed to mermaid traditions of Skye

Akin to this part of the subject is the folk music, and also the folk-dances, the fairy tunes which old pipers heard underground when they slept on fairy knolls, and the similarity in the phrasing and modulation to Egyptian and other Eastern types There seems little doubt that the reel was originally a war dance, the Skye eightsome a religious dance, and both have Eastern analogies

The Saxon or Teutonic colonists, usually called Lowland Scots, have an entirely different group and character of folk tales Here we find mostly stories of ghosts and hauntings The Elementals are neither the gentle, kindly folk of the pure Celt, nor the fierce and revengeful type of the Scandinavian, but rather the gruesome and horrible Also here we get the witch legends, and compacts with the devil These are very little to be met with among the Celts of the West A witch there is a creature of the mist, usually not in any sense human But among the Lowland Scots a witch is a perfectly human woman, who has made a compact with the devil

The blending of all kinds of folk-lore is found in the Province of Moray, which for that reason is one of the most interesting parts of Scotland for the study The aspirations of the great Somerled brought an influx of Celts and Scandinavians, and the Teutonic settlements of the eleventh and twelfth centuries introduced a strong Saxon element, all of which may be traced in the stories commonly told among the peasants to-day

---

6 *Report on the Distribution of Artificial Islands in the Lochs of the Islands of Scotland* —See Reports, p. 201

7 *Pigmy Flints in the Dee Valley* [1] *By* Miss H Leslie Paterson

The minute and finely chipped implements of stone called 'Pigmy Flints' are of at least four distinct varieties They are (1) the shouldered or triangular pigmy flint, (2) the rounded and pointed, (3) the crescent, (4) the rhomboidal form They are manufactured from small flakes, the natural edges of which are in many cases left untouched, whilst the thicker sides or backs are beautifully finished by fine secondary flaking The use of these tiny tools seems as yet a profound mystery, although there are many conjectures, and the periods usually assigned to them are Neolithic and Early Bronze Age They are found in India, Palestine, Egypt, North Africa, Southern Spain, France, Belgium, and Great Britain

Until quite recently pigmy flints were not known to exist north of the Forth, and it is really due to that tireless enthusiast, the Rev Reginald A Gatty, LL B , of Hooton Roberts, Rotherham, Yorkshire, that we are now able to extend their location to Kincardineshire Through reading an article from his pen entitled 'The Home of the Pigmies,' which appeared in 'Chambers's Journal,' April 1905, we received both knowledge and stimulus The result was patient search, and, just as it chanced, our home site (on a river terrace of great beauty and shelter) had found favour in the eyes of those distant people who fashioned these mysteriously tiny and unaccountable implements The collection is as yet small, but each flint is a real fact, and multiplication of them, whilst

[1] To be published in full in *Man*

it is important, is not of the superimportance of those already found Their presence in river terraces is of considerable moment, as a careful study of the rate of erosion of the river gives us data for an estimate of the interval between our present civilisation and theirs

---

8 *An Account of the Discovery of Human Skeletons in a Raised Beach near Gullane* *By* Professor A KEITH *and* Dr E EWART.

MONDAY, SEPTEMBER 9

The following Papers and Report were read —

1 *Excavations at Halos in Achaea Phthiotis*
By A J B WACE, *M A* , *and* M S THOMPSON, *M A*

Excavations were carried on at two places, just outside the city wall, where a group of tombs was discovered, and at a tumulus about fifteen minutes away. The tombs close to the wall were with one exception, which was circular in plan, all rectangular cist tombs built of slabs The vases found in them all belong to an early phase of the 'geometric' style in which the designs, though geometric, recall the decoration of the preceding period The only metal object found was a bronze pin with twisted top Similar tombs also belonging to the early Iron Age have been found at Theotoko in Southern Magnesia and in Skyros

The tumulus, which forms one of a group, was composed of large river-worn stones with only a small admixture of soil It was found to conceal sixteen separate pyres Each pyre was covered by a cairn of larger stones, usually unhewn slabs, and beneath these were a heap of pottery, fragments of bone, iron weapons, or bronze fibulæ Six pyres contained, besides pottery, which was common in all, bronze fibulæ and only small iron knives, the remaining ten pyres contained no fibulæ, but swords, spears, and knives of larger size These ten seem therefore to have been men's pyres and the others to have been those of women A man's equipment was a long sword, a spear, and two or more knives, all of iron, there was no trace of a helmet or of body armour The pottery found all belongs to the 'geometric' age, but is distinctly later in style than that from the tombs by the city wall

---

2 *On a 'Find' of Bronze and Iron Javelins in Caria*
By Professor W RIDGEWAY, *F B A*

In the 'Early Age of Greece' vol I , I argued (1) that the culture of the Early Iron Age of Central Europe was that of the Homeric Acheans, who had brought it with them into Thessaly, where they were settled in Homeric times, and (2) that the older race and those who could not obtain the new metal had to content themselves with weapons and implements of bronze, and that (3) there was consequently a distinct period of overlap when bronze and iron weapons were in use side by side This accounts for the fact that whilst the weapons in the hall of Odysseus are collectively termed *sideros*, yet in descriptions of individual combats the phrase 'smote him with the *bronze*' (*chalkos*) is generally used As the language of Homer is that of the older race, whose bards sang the praises of the Achean lords, it is natural that poetic diction used the name of the older metal for weapons long after the new was in use, as indeed is the case in every-day language—*e g* , we speak of 'instruction in *musketry*,' though the Brown Bess musket has not been used in the Army for some sixty years The tombs of East Crete have already given evidence for the overlap of bronze and iron swords. The 'find" now described was discovered at Cnidus, in Caria, in 1911. It consists of six bronze javelin-heads, five iron javelin-heads of exactly the same type, a small iron knife, and one or two iron fragments, and a small whetstone

perforated for suspension. This association of javelins of both metals puts it beyond doubt that weapons of both metals were in use at the same time, as is represented in Homer If a bard had been celebrating the exploits of the owner of this set of javelins he would surely have said that he 'smote his foe with the bronze' (*chalkos*), even though he had slain his adversary with one of his iron specimens

3 *Report on Archaeological and Ethnological Investigations in Crete*
See Reports, p 224

4 *Discussion on Megalithic Monuments and their Builders.*

(1) *Introduction by* Professor G ELLIOT SMITH, *M A , M D , F R S*

I need not explain the circumstances that impelled me to intrude my opinions in a domain of ethnological inquiry of which I have no special knowledge beyond the mere statement that collateral studies of the remains of the people of the Megalithic Age in the Mediterranean area suggested a solution of the problems in question which leading authorities on megalithic monuments have frankly confessed their inability to solve

No adequate explanation of the significance of dolmens, cromlechs, alignments, and all the other works in stone associated with them, can be found unless due recognition is given to (*a*) the identity of the ideas which prompted their construction, and the essential resemblances in their plan, (*b*) their geographical distribution—their absence from large central continental areas, and their wide extent along continuous coastal and insular territories, (*c*) the chronological sequence of their construction, the site of their earliest appearance being somewhere in the neighbourhood of the Eastern Mediterranean, and progressively later in date as we go either west or east—towards Ireland and Scandinavia, or Japan and the Pacific Islands, respectively, (*d*) the coincidence of their first appearance in most lands with the last phase of the Stone Age or the commencement of the Age of Metals, and (*e*) the improbability of theories of independent evolution, among widely separated races of mankind, of identical ideas which find expression in the same way in buildings of similar design and materials

If, as some of my critics have argued, the impulse to build megalithic funerary monuments was a phase of culture through which all mankind has passed, why were the people of Central Europe exempt from this instinct—for this hypothetical inborn impulse to erect elaborate stone monuments just as the ants build their hills can only be regarded as an instinct—when their littoral relatives in the Mediterranean area and on the north west of Europe were stirred by it to cut rock-tombs and build dolmens? Why, also, if this hypothesis has any basis of fact, did the ancient inhabitants of Ireland not get their 'impulse' until more than a millennium later, and the people of Japan until two millennia later, than the people of Egypt?[1]

It is now generally admitted[2] that in the Mediterranean and Western European areas the erection of megalithic monuments did not begin until the latter part (Æneolithic) of the Age of Stone, or the commencement of the Age of Metals No theory that leaves this chronological coincidence out of account can have any cogency

The most ancient copper tools so far discovered and accurately dated come from Egypt In Egypt every stage in the development of the art of working metals is known, and so far as we know this knowledge was acquired in Egypt earlier than elsewhere Egypt also supplied, in the habits of her prehistoric inhabitants, the predisposing circumstances that led to the discovery of copper

[1] See Geo Coffey, *New Grange (Brugh na Bonnne) and other Incised Tumuli in Ireland*, Dublin, 1912, and the writings of Gowland, Pastor, and others on Japanese megalithic monuments, *Zeitsch f Ethnol*, 1910, p 601

[2] See the excellent summaries of literature in *L'Anthropologie*; also Peet, *The Stone and Bronze Ages in Italy*, 1909, chap. xi.

and the inauguration of the Age of Metals If Reisner's theory of the origin of copper-working in Egypt be admitted, it follows as a necessary corollary that the Age of Stone came to a close first in Egypt, and in other countries only at some later time, as the Egyptian knowledge of metal-working gradually became diffused from tribe to tribe amongst her neighbours, and from them to others more remote. It probably took more than a thousand years for this knowledge (and with it the Age of Metals) to reach Western Europe, and more than two thousand years to reach Eastern Asia, and possibly another thousand years more for it to cross the Pacific to America It never reached Australia until modern Europeans took it there

It is common to find definite evidence, both in the physical characteristics of the human remains buried in association with these monuments and in the objects buried with them, of intercourse with neighbouring peoples at the time megalithic structures were erected These monuments were not built by any particular group of people or race, who wandered about from place to place throughout the greater part of the world erecting these memorials of their pilgrimage, nor are they the results of some common impulse of humanity to evolve in widely separated localities the idea of constructing stone monuments of similar design and for similar purposes They are rather the material witnesses to the spread of one definite idea, which was handed on from people to people, each population giving to its neighbour a contribution of its own flesh and blood, and with this some of its material culture, customs, and beliefs, and that such a radiation of new practices took place when the new knowledge of metals was forcing more intimate relations between neighbouring peoples and gradually leavening the sluggish culture of the Stone Age

In the Neolithic Age in North Africa, Europe, and Western Asia the grave was looked upon as a dwelling in which the corpse, lying flexed upon its side, continued some sort of existence, and needed food and implements and utensils Even before the invention of metal tools for working stone, rough slabs of stone were sometimes employed for roofing, or lining, or for piling upon graves to protect them from the depredations of jackals or other desecrators But when metal tools were invented in Egypt, and it became possible to work stone upon a large scale, one of the first uses to which the new craft was put was in cutting extensive chambers in the rock as dwelling houses for the dead, and later of building temples (of great masses of stone) to which the relatives and friends of the deceased could bring their offerings of food

Thus, at a time long anterior to the erection of stone buildings or rock-cut chambers elsewhere, the Egyptians had built the vastest funerary monuments the world has ever seen—the Pyramids of Giza—as gigantic mausolea for the reception of the bodies of their rulers, and in association with each pyramid a megalithic temple of offerings

Is it at all reasonable to suppose that these mighty achievements in Egypt can have failed to influence the neighbouring peoples? Must we look upon the sudden change of burial customs that occurred shortly afterwards—*i e*, at the dawn of the Age of Metals—in neighbouring Mediterranean lands, and the institution of megalithic building and rock cut chambers as independent evolutions of custom, wholly unrelated to the great events in Egypt? Must we look upon the change in the position of the corpse, which is associated in Egypt with the culmination of the Pyramid Age, and in other Mediterranean lands with the introduction of the rock-cut chamber and the megalithic temple, as being a mere coincidence? Is the essential identity of plan of the Egyptian pyramid and, for instance, the New Grange monument in Ireland, as well as many other Early Bronze Age buildings in Western Europe, due to the independent evolutions of ideas among different peoples? Is it a mere coincidence that the dolmen idea, starting from the Eastern Mediterranean littoral, should have manifested itself at a series of spots west to the British Isles and east to the Pacific Isles, in regular and orderly chronological sequence along coast-lines? Is this the way the independent evolution of the same idea, with such a manifest suspicion of inter-tribal and inter-racial collusion, works out in practice? If so, why do not the dwellers in the midst of continents receive their share of the inspiration? Why should the Japanese and Koreans wait for their idea until Malaysia, Burma, and India have got it, and why did it not occur to the peoples of the latter regions to build megalithic monuments until Egypt and Syria had built theirs? Is it credible

that the peoples of Algiers and of the Madras Presidency evolved out of their inner consciousness, quite independently the one of the other, the same idea of a dolmen-crowned tumulus encircled with concentric rings of stone slabs?

If one considers the details of the history of Egypt and the evolution of her arts and crafts and her customs and beliefs during the beginning of the third millennium B.C., and bears in mind either the chronological order of appearance and the geographical distribution of megalithic monuments in the various countries on the one hand, or the general plan, the structural details and the ideas exemplified in the evolution of tomb construction in Egypt and the other places where megaliths occur, it seems to me wholly inconceivable that any other conclusion can be reached but that the idea of tomb building, which was slowly evolved in Egypt during the fourth and third millennia B.C., was handed on from people to people, not only along the coast-line of the Mediterranean and Western Europe, but also along the whole Asiatic littoral, from that of the Red Sea to Southern Arabia and Persia, and thence to India, Ceylon, and Burma, to Indo-Malaysia, Korea, Japan, and the Pacific Islands, if not beyond to America.

The history of the spreading of cultures and religions in more recent times illustrates and confirms the hypothesis set forth here. For instance, the extension of the influence of Islâm from Arabia, to Spain in the West and Malaysia and Japan in the East, and the early maritime exploits of the Phœnicians, Arabs and Indians illustrate the means by which widespread interchanges of peoples, cultures, and ideas are brought about.

No doubt in each place the common idea was worked out in more or less independent detail, but the case I want to put before you, and, by means of this series of provocative questions, stimulate you to attack, is briefly that the *idea* of megalith-building originated in Egypt soon after the invention of metal tools, and spread from tribe to tribe, usually along coast lines (because maritime habits are the most potent incentive to inter-racial intercourse) until the whole world was encircled by it. Such an idea would necessarily outstrip the culture which gave birth to it in Egypt. In other words the cult of building funerary monuments of great blocks of stone would be carried by these early missionaries to foreign lands more readily and more quickly than the skill to make and use metal tools. Hence the megalithic culture, which was evolved in Egypt as one of the results of the discovery of metals, made its appearance in other lands just before the dawn of the Age of Metals.

(ii) *Are we justified in speaking of a Megalithic Race?* *By* T. Eric Peet, *B.A.*

Since 1872, when General Faidherbe published his observations on the dolmens of Algeria, the question of the origin of the megalithic monuments has been keenly discussed. The main point at issue is whether they were built by a single race or by a number of entirely different races or peoples, and, in the latter event, whether they arose independently among various peoples or spread from a single centre. The independent origin of the monuments has long had a defender in Mr. A. L. Lewis. But it is *a priori* unlikely that the use of huge blocks of stone, where much smaller ones would have served the purpose equally well, should have arisen in many centres independently. Moreover, megalithic architecture follows certain definite rules. Its main principle is the use of a course of orthostatic slabs, often surmounted by courses of horizontal masonry. Its methods of roofing are two, the use of large slabs laid across from wall to wall and the employment of corbelling, in which the upper courses of the walls overlap successively inwards to form a vault or dome. It is improbable that these principles should have arisen in so many places independently. Buildings exactly similar in type, corresponding even in small details, are found in places far apart from each other. The dolmen occurs in almost every part of the megalithic area, while the curved façade, which sometimes occurs in the megalithic monuments, is found in Malta, Sardinia, the Balearic Isles, England, Ireland, Scotland, and the Isle of Man. Further similarities of detail are to be found in the pierced blocks so often found in megalithic tombs, and in the so-called 'cup-markings.' The theory is also rendered unlikely by the fact that most of them date from much the same period, and that their geographical position, mainly along the edges of a vast sea route, points to connection rather than independence.

Assuming that there is a connection between the monuments of the various regions, was the custom of building such structures spread from its original source by influence or by actual immigration? Montelius supposes the custom to have been carried from one country to another by the influence of trade, &c This involves the assumption of great trade-routes in the neolithic age—an assumption which there is little evidence to justify Further, the theory demands that the inhabitants of certain countries—*e g*, Spain—abandoned the method of burying the dead in the bare earth for burial in dolmens and other megalithic tombs, solely because certain other peoples with whom they had trade relations disposed of their dead in this way To suppose that such a change was wrought by mere trade relations and in one country after another is impossible

There remains the explanation that megalithic architecture was practised by some great race which at the end of the neolithic age spread over parts of Europe, Asia, and Africa, carrying this method of building with it This involves a great racial movement, but not a single valid objection has ever been made against it Montelius' criticism is based on an Aryan theory which has now been generally abandoned Déchelette sets it aside with the remark that 'anthropological observations have long since destroyed this risky hypothesis,' but he omits to tell us what these anthropological observations are There is nothing *a priori* absurd in the idea, and we have good parallels in the movement which gave the Mediterranean its early neolithic population and in the Arab migrations of the Middle Ages As to the direction of this movement we have no evidence, but it is possible that Mackenzie is right in placing its starting point somewhere in North Africa

---

5 *The Prehistoric Monuments of Malta and Sardinia* *By* THOMAS ASHBY, *D Litt*

The British School at Rome has had the advantage during three seasons of co operation with the Government of Malta in the excavation of several megalithic monuments on the islands of Malta and Gozo, some of which were being examined for the first time, while at others, such as Hagiar-Kim and Mnaidra, which were already known, supplementary excavations were conducted, which produced objects of some importance The results of the work show that these monuments undoubtedly belong to the neolithic period, or at latest to the very dawn of the age of metals The pottery is characteristic, and has affinities with wares discovered in Western Mediterranean lands where the megalithic civilisation flourished (Sicily, Sardinia, Spain, the Balearic Islands, &c), and in remains connected with it or related to it Not a trace of metal was found in the whole course of these explorations, nor in the excavation of the hypogeum of Halsaflieni, an enormous ossuary which is certainly contemporaneous with the megalithic monuments above ground These buildings were probably in part sanctuaries, in part dwellings, the original part of the building being generally that devoted to sacred uses, with a very distinct and typical plan, and the cult was symbolised in the *baetyli* found sometimes in isolation, but more often in architectural union with the dolmen like niches which frequently appear in these edifices [1] The *baetyli* no doubt symbolised the departed heroes who were worshipped there, but it seems improbable that these monuments actually served a sepulchral purpose the burials which have been found at Torri ta Santa Verna, in the island of Gozo, which was excavated in 1911, while apparently of the neolithic age, belong to the latest phase of the existence of the building And besides the hypogeum of Halsaflieni (which was probably not the only one of its kind), many burials of the neolithic period have recently been found by Professor Tagliaferro in a cave at Bur meghez, near Mkabba, while a well-tomb came to light in November 1910 near Attard, and further researches in the caves of the island will no doubt be fruitful In Sardinia the School has confined itself to surface exploration, the excavations being in the hands of the Italian authorities, whose friendliness and courtesy deserve full acknowledgment. Dr. Duncan Mackenzie, in the course of three campaigns (in the last

[1] Actual menhirs and dolmens, it should be noted, are not lacking in Malta and Gozo, but there is unluckily no soil around them to excavate.

two of which he was accompanied by Mr F G. Newton as architect), has discovered a number of dolmens, some of which form the transition to the 'tombs of the giants'—long tombs used for a number of inhumation burials like the barrows and cairns of our own islands, and found almost without exception in close connection with the nuraghe, the fortified habitation of the megalithic people of Sardinia Both in these structures and in the megalithic monuments of Malta we notice the characteristic combination of the orthostatic slabs with courses of ashlar masonry above them, which project to form the roof or covering, and the curved area in front of the façade; while the single architraves of the nuraghi also find a parallel in Maltese architecture, which however in many ways stand alone The structure and plan of many nuraghi were also studied, and their strategic disposition carefully observed It is clear that they were so arranged that signalling from one to the other would have been easy, and that they were fortified habitations, and not tombs, is clear from many considerations—not least from the existence in several cases of a village of circular beehive huts under the protection of the nuraghe Of these by far the largest is that discovered by Cav I Sanfilippo near Gonnesa, in the neighbourhood of Iglesias

---

6 *Excavations in the Ancient Hill Fort in Parc-y-Meirch Wood, Kinmel Park, Abergele, North Wales* By WILLOUGHBY GARDNER

This hill fort, Dinas or Din, is situated on the crown of a rocky spur, 550 feet above sea-level, it has an interior of about five acres It is, roughly, pear-shaped, with the broad end to the south The site is a stronghold by nature, and has a commanding position All along the west side it is precipitous, and on the east very steep, only at the southern end is it connected by a level neck of land with the uplands behind Its natural defences were at some unknown date supplemented by strong fortifications These were specially necessary across the 'neck,' and here consist of a huge main rampart and ditch, a second small rampart and ditch, and a third rampart and ditch There were less strong fortifications across a spur at the north end and a rampart along the east side The main entrance was unearthed to the south-east, and another has been located near the north

The excavations occupied a month with ten labourers and amateur help Work was directed to the ramparts and ditches, the south-east entrance, and a few points in the interior The two first showed remarkable features, noted later The entrance was found to be a passage through the ramparts, with side walls of rude dry masonry prolonged to a length of 38 feet It had a roughly cobbled roadway, in which were three pairs of holes for wooden gateposts Upon this roadway and in various places elsewhere many relics were unearthed Among these were large quantities of broken bones of various domestic animals consumed for food by the former inhabitants, broken pottery (much visibly of Roman manufacture), showing urns, bowls, and saucers, made in common red black, grey, and white wares, with some fragments of the finer 'Samian', broken objects of household use in stone, such as pot boilers, mealers, whetstones, and spindle-whorls In places little heaps of charred wood, marking ancient hearths, were found, near some of these was slag from the smelting of iron and of lead Sling-stones and corroded iron spear-heads were the only weapons found No dwellings have yet been identified, but the discovery of large iron nails suggests that they were made of wood The ornaments found were some beads and a small bronze ox-head These objects are difficult to date, but fortunately there occurred with them in various places a number of Roman coins of different Emperors, evidently current among the native population The majority were minted A D 335 to A D 353, and the latest about A D 380 The inference from the relics is that the site was extensively occupied during the fourth century

But the excavations revealed an earlier origin for the hill fort For (*a*) the main rampart was found to cover a smaller and earlier one, (*b*) the third rampart was shown to have been added to the original defences, as it was thrown up across a road leading from the entrance, (*c*) further excavation in the entrance itself revealed another road (of better construction) below the fourth-century thoroughfare; and (*d*) just before the explorations came to an end, yet a third road,

with different post holes and side walls, was brought to light The ditches also afforded evidence that at some period the fortifications were destroyed The relation of the superincumbent roadways and entrances to the various ramparts and ditches, as also their respective dates, will have to be worked out by future excavation The interior area still offers a large field for investigation, and the defences at the north end and the north-east entrance remain untouched

The ancient name of this Dinas was *Dinorben* 'Orben' is a word of Goidelic origin, so this native hill-fort apparently obtained its title before the advent of the Brythonic tribes into this district

TUESDAY, SEPTEMBER 10

The following Papers and Report were read —

1 *Discussion on Palæolithic Man*

2 *On the Physical Characters of the Human Remains found by Mr Quibell in Mastabas of the II and III Dynasties at Sakkara By* Professor G ELLIOT SMITH, *M A , M D , F R S*

The problem that specially called for solution in the examination of this series of skulls was whether there was any evidence of foreign admixture in the population of the Second and Third Dynastic period in Lower Egypt, such as is known[1] to have occurred by the time of the Fifth Dynasty The answer given by this material is quite definite The people buried in these earliest Sakkara mastabas showed numerous unmistakable alien traits, but at the same time they exhibit such a series of gradations, passing into the commoner type of Egyptian, as to raise for discussion the interesting problem whether real blending of characters occurs in human mixtures?

The complete evidence and the discussion of its significance will be published in the report of the Committee of the Association on the Physical Characters of the Ancient Egyptians [1]

3 *Report on the Physical Characters of the Ancient Egyptians*
See Reports, p 268

4 *The Earliest Evidence of Attempts at Mummification in Egypt By* Professor G ELLIOT SMITH, *M A , M D , F R S*

In previous notes[2] the earliest evidence of mummification in Egypt that I was prepared to admit as being unquestionable was that afforded by the mummy said to be that of Ra-nefer, found by Professor Flinders Petrie at Medûm in 1892, and now lodged in the museum of the Royal College of Surgeons in London The earliest date that can be assigned to this mummy is the age of Snefru, the beginning of the Fourth Dynasty, although I believe there are reasons for thinking it may belong to the period of the Fifth Dynasty

During a visit to Egypt last winter I was permitted by Mr J E Quibell to examine the human remains found by him in a series of mastabas at Sakkara, belonging to the period of the end of the Second and the beginning of the Third Dynasties In the burial chamber of one of these mastabas (referred to as No 2262 in Mr Quibell's notes) the skeleton of a woman about thirty-five years

[1] *Ancient Egyptians* (Harpers), London, 1911, p 114

[2] 'Notes on Mummies,' *Cairo Scientific Journal*, February 1908, *Nature*, 78, p 342, 'The History of Mummification,' *Proc Roy Phil Soc of Glasgow*, 1910.

of age was found completely invested in a large series of bandages—more than sixteen layers still intact, and probably at least as many more destroyed—ten layers of fine bandage (warp seventeen and woof forty-eight threads to the centimetre), then six layers somewhat coarser cloth, and next to the body a series of badly corroded, very irregularly woven cloth, much coarser (warp six and woof fourteen per centimetre) than the intermediate and outer layers Each leg was wrapped separately, and there was a large pad on the perineum The bandages were broad sheets of linen rather than the usual narrow bandages The body was flexed, as was usual at this period

In the wide interval between the bandages and the bones there was a large mass of extremely corroded linen, whereas the intermediate and superficial layers of cloth were quite well preserved and free from corrosion, except along a line where the cloth was corroded to represent the rima pudendi—a fact of great interest when it is recalled that in the Fifth and probably the Fourth Dynasties it was the custom to fashion (in the case of male mummies) an artificial phallus

The corrosion is presumptive evidence that some material (probably crude natron) was applied to the surface of the body with a view to its preservation If so, this is the earliest body with unequivocal evidence of an attempt artificially to preserve or prevent decomposition in the soft tissues

The specimen (now in the museum of the Royal College of Surgeons) was placed at my disposal by Mr Quibell (acting with the sanction of Sir Gaston Maspero, Director-General of the Department of Antiquities in Egypt), and I was able to examine it at Sakkara, whilst I was engaged (January 1912) in carrying on the work of this Association's Committee on the Physical Characters of the Ancient Egyptians

5 *Colour Photographs of Theban Tombs* *By* R Mond

6 *Tribes of the West and Central Sudan* *By* P Amaury Talbot, *B A*

In this paper I have attempted to sketch the relations of the more important peoples between the Gulf of Guinea and the Central Sudan Starting from the coast, the three main divisions of Southern Nigerian races, also found in parts of the South Kamerun, are —

1 The *Yoruba*, a negro race of great intelligence, driven, according to their own tradition, southward from the Sudan by the Fulani
2 The *Ibos*, mostly delta people, and probably the earliest surviving settlers in this part With these should be included the Ibibios, of whom the Efiks of Calabar are a branch
3 *Cross River tribes*, which I have had special opportunities of studying, comprising the Ekoi, Ojo, Etung, and Ododop Of these the first named are interesting, as marking the farthest point reached by the Bantu invaders, and also on account of their distinctive religion The cephalic indices range from 74 to 76 They seem to have come over from south of the Nile, and possibly represent some of the first Hamites to appear in Africa, though they now show strong traces of negro strain Hamitic influence is still clearly seen in their worship of a sky God and veneration of crocodile and snake—in their customs, ordeal, &c —their belief in were-animals, and their decorative *motifs* Certain indications would seem to show that the Cretan Axe cult is not yet totally extinct among them.

To the north of the Cross River dwells that strange and little known race, the Munchi Next come the Nigerian pagans, north of the Benue Marragi, Kilba, Baburr, and Kerri-Kerri Amidst these dwell their victorious invaders, the Fulani, Hausa, Bornuese, and Fikans

According to the tradition of the latter, Bornuese and Bagirimi came over with them from Yemen This is apparently confirmed by measurements which show cephalic indices varying only from 74 1 to 74 5, thus nearly approaching those of the ancient Egyptians, and by a Fikan skull, recognised on sight by Professor

Elliot Smith as of Nilotic affinity. In common use by all these peoples at the present day are wooden throwing weapons almost identical in shape with those which come down to us from ancient Egypt

Eastward in the Cameroons and French Central Africa some tribes are to be found whose architecture shows points of peculiar interest.

First come the Mundong, with their compounds like mediæval fortresses and turret-shaped, domed granaries, entered by circular apertures, strongly reminiscent of the doors and windows of ancient Chinese architecture

Next come the Tuburi, chiefly remarkable for their plaintive melodies

Thirdly, the Wadama, a coal-black, magnificently built race, and

Fourthly, the Banana, primitive near Tordé, where the whole artistic sense of the people seems to have expended itself on their elaborate fireplaces, but who, as one passes up the Logone, develop a more and more wonderful style of dwelling, until at Musgum itself is to be found the unique cone-shaped type, acclaimed by architects as the perfection of the arch

The three last-named tribes are negroes with a cephalic index of c 77 They probably arrived before the Bagirimi and Kanuri, by a more southward route, and seem to have affinity with the Bandawi and other tribes of the South-Western Bahr-el-Gazal

To the north, beyond a great marsh, come the more civilised Bagirimi, Kotoko, Buduma, and Kanembu Of these, all save the Bagirimi appear to represent an early invasion of Nilotic negroes, allied to the present-day Shilluks and Dinkas, to whom they show strong resemblance in height and in the marked dolichocephalic shape of head

For refugees from all these tribes Chad forms a sanctuary, and an interesting point in the comparative measurements is the extraordinary span of arm attained on the one hand by the Buduma, probably due to the greater part of their lives being spent in poling over the lake, and on the other by the Banana and Wadama, whose chief weapon, a gigantic club, seldom laid aside, may have been instrumental in bringing about the survival of the longest-armed

7 *Contributions to Sudanese Anthropometry* *By* W L H DUCKWORTH, *M D , Sc.D*

The measurements and other observations discussed in the following paragraphs were made by Oliver Atkey, Esq , F R C S , Medical Inspector for Dongola Province, Anglo-Egyptian Sudan Mr Atkey generously volunteered in 1910 to collect anthropometric data in the south-eastern part of the Sudan But the claims of his official duties prevented him working up the data thus collected, and consequently he has sent me the greater part of his material

The observations are recorded on cards, and they include descriptive as well as numerical data The descriptive part includes records of the tribes and their sub-divisions, as well as certain important references to the marriages of cousins which appear to be customary and locally distinctive

The number of individuals examined amounts to 136, but Mr Atkey's letters to me indicate that he has other observations which, however, have not yet reached me The 136 men thus observed are found to come under the following heads as regards their relations, six groups are conveniently recognised, viz —

A *Jemeni* —These come from the mountains near Sanae in Arabia

B *Amarer* —Mountaineers from the Red Sea coast of the Anglo-Egyptian Sudan

C *Hadendowa* —They are allied to the Amarer

D *Kababish* —Measured in Dongola Province, west of the Nile They are believed to be allied to groups B and C above

E *Somali*

F *Miscellaneous*, including Shilluks, Jaalin, negro of Kordofan, &c.

In addition to the records mentioned above, Mr Atkey has sent me a valuable statement descriptive of important features of each of the groups (A. to E). This statement will be published with the detailed account of which the present report is but a partial abstract.

In the present instance, groups A and B will be considered alone. The numbers of individuals are as follows.—

Group.		Group.	
A. *Jemeni*	Thirty men.	D. *Kababish*	Ten men.
B. *Amarer*	Sixty men.	E. *Somali*	Three men.
C. *Hadendowa*	Twelve men	F. *Miscellaneous*	Twenty-one men.

The Jemeni men are of course immigrants into the Anglo-Egyptian Sudan Of the remainder, most were observed by Mr Atkey in regions known to have been inhabited by the several tribes for a considerable period This statement is important in view of the somewhat haphazard way in which some other observers have collected their materials in this part of the world

The two groups, Jemeni and Amarer, selected thus for comparison, confront each other on opposite shores of the Red Sea in its more southern part In the first place, some numerical data may be considered in the form of averages Five of the measurements selected for this purpose are tabulated as follows —

Character	Jemeni	Amarer
1 Stature	1650	1710
2. Nasal Index	69	73
3 Cephalic Index	77 47	76 89
4 Upper Facial Index	52 3	52 3
5. Interocular width	106	106

It is clear that the first two characters reveal a difference that would not have been suspected had reliance been placed on the remainder, including the notorious cephalic index

Again, the examination of those two characters, viz , stature and cephalic index, shows that the differences observed are such as suggest an approach of the Amarer men to a type which may be described as 'Nilotic '

The pursuit of this inquiry into the domains of the descriptive characters leads to the statements following —

Character	Jemeni	Amarer
6. Eye-colour —Position of the mean value in the scale of eye-colours as measured the lightest up to the darkest (100)	55	60
7. Skin-colour (of unexposed skin) —Position of the mean value in the scale of skin-colours as measured from the lightest to the darkest (100)	18 45	47 75
8. Hair of Head —Position in the scale, measured from the straightest to the most closely curled (100)	49 3	70 13

In two characters (6 and 7), the Amarer stand nearer the more deeply pigmented end of the scale In the third character (8), they show a markedly greater tendency to a frizzly type of hair on the head The inference drawn above from the stature and the nasal index is confirmed hereby

9 Yet another test may be mentioned It has been seen that the mean value of the cephalic index provides no evidence of note as to a contrast to be drawn between the two groups in question But if the series of individual cephalic indices be examined, a distinction will be detected, although the average values remain silent on this subject

The occasional occurrence of brachycephalic heads both among the Jemeni and the Amarer is very noteworthy. Mr. Atkey was much impressed by it And indeed, out of the thirty Jemeni, no less than ten have a cephalic index of 80 or upwards, and one individual provides an index of 87

The proportion of brachycephalic heads among the Amarer is just half of its value among the Jemeni, for out of sixty Amarer men, again ten provide an index of 80 or upwards Moreover, the highest individual value is 85, though there are two instances of 84 The character of brachycephaly is clearly less frequent and less intense among the Amarer The latter are also taller than the Jemeni, they have wider noses, darker eyes and skin, and more curly hair. All these facts point in the same direction.

At present my chief object is to place on record the facts of Mr. Atkey's

valuable work The observations themselves, and the extensive series of averages, standard deviations, and other numerical results already extracted by me from the data will be published in detail at the earliest possible opportunity.

---

8 *An Early Dynastic Cemetery in Egypt*
By Professor W M FLINDERS PETRIE, *D C L , F R S*

An extensive cemetery was found by the British School only thirty-five miles south of Cairo, which dates from the earliest historic age down to the Pyramid period, during the five dynasties O to IV About six hundred burials, spread over a mile of desert, have been recorded, and a great number in addition had anciently been destroyed This cemetery (known as Tarkhan, from the name of the nearest village) will be one of the standard sources for our knowledge of the early historic civilisation It is the most northerly settlement known of so early an age The precise period was ascertained by a tomb with pottery of a pre-Menite king, and another very large tomb with pottery of Narmer-Mena The presence of so large a cemetery, for the most part before the age of Mena, shows that there must have been a chief town of this period in the region of the present Kafr Ammar This town preceded the founding of Memphis, and appears to have been started as the northern capital of the dynastic race before Memphis, and gradually fell out of use under the early Pyramid kings

The special feature of the cemetery is the extraordinary preservation of both woodwork and clothing

Although the Egyptian houses of that early age have all perished in the cultivated plain, yet some precious pieces of house timber were found re-used in the construction of the coffins These pieces agree with the explanation of the panelled or recessed decoration in buildings, as copied from timber houses, built of overlapping vertical planks The planks have rows of tie-holes cut in the edges for lashing them together, so that they could slide one over the other when shrinking or swelling Some examples were deeply weathered outside and burnt inside, showing that a house had been burnt down and the scraps used as waste for coffin-building

Coffins made of basket-work, reeds or withies, were also found Wooden trays, both for domestic use and of large size for biers, were discovered in firm condition The bed frames were varied in form and often perfectly preserved, sometimes they even retained the rush-work webbing or decorative plaiting of palm fibre The poles were beautifully tapered and jointed, usually with carved bulls' legs to support them

A great quantity of pottery was found, and some three hundred alabaster vases and dishes, mostly perfect Pottery jars in one tomb had excellent drawings of the fore part and hind part of a zebra That the sacred beetle was then venerated is shown by a reliquary carved in the form of a beetle, with the lid kept in place by the string for suspension At Memphis a gigantic sphinx of alabaster has been found, lying between the two well-known colossi This is the largest sphinx that has ever been transported, being 26 feet long and 14 feet high, and weighing about eighty tons At the north gate of the temple of Ptah, another sphinx has been found, carved in red granite, over 11 feet long and 7 feet high, inscribed by Rameses II Near this was a fine group in red granite, representing Rameses II and the god Ptah standing Here also the faces are quite perfect At Heliopolis the top surface is dated by the pottery to the sixth century B C , and there is scarcely a trace of the Ptolemaic, Roman, or Arab ages

The temple enclosure was three-quarters of a mile long It was surrounded by two great walls, each 40 to 50 feet thick, which have been traced on all sides and planned This wall was built in the Nineteenth Dynasty In the north-west corner was a fort, also of massive brickwork, but this could not be traced far owing to the obstruction of a cemetery and cultivation The great surprise, however, was finding an earthen fortress of the same type as that at Tell el Yehudiyeh, attributed to the Hyksos This fort at Heliopolis is of the same form, a rounded square, the same size across (quarter of a mile), and has the

same thickness of wall—over 100 feet It likewise has no gateway in the axis, the walls or bank, where it is opposite to the obelisk, being still 12 feet above the base of the obelisk

---

9 *Archæological Remains of Primitive Ethiopian Races discovered in Southern Sudan* By HENRY S WELLCOME

During an expedition to the Sudan in the winter of 1900 I found various neolithic objects In 1910 I resumed my researches, and after extended exploration, discovered the site of an ancient settlement at Gebel Moya, Sennar Province. Excavations have been carried out in the face of innumerable difficulties in securing labour and in controlling the turbulent, lawless natives; however, by just and fearless measures I finally won their full confidence, and was thus enabled to influence them to modify their habits of life About five hundred men were employed in the first and more than six hundred in the second season

The site is located in a basin of about 200,000 square metres, high up in the hills, within a natural fortress of great strength

In the course of the excavations many objects were discovered, including the following —

Extensive series of stone implements, including axes, adzes, chisels, planes, and hammers, in nearly every stage of evolution, from the most primitive natural forms to perfectly worked and highly finished examples, also many other tools of various materials used in industries, and flaked arrow-heads of various stones

Pottery in great variety, ranging from crude primitive types to highly finished and elaborately decorated examples of extraordinary quality and grace, mostly in fragments, but some entire

A considerable number of potters' implements, and a variety of pigments

Rock pictographs

Numerous figurines of clay representing human and animal forms

An extensive variety of beads, amulets, and other ornaments, varying from those of a very primitive type up to highly finished stones of a more precious nature

Some unique objects, including lip, ear, and other ornaments in infinite variety, many of these found *in situ*, proved conclusively their purpose

Remains of workshops, containing various implements, beads, and other ornaments in all stages of manufacture (indicating an industrial settlement), and a very few objects of copper, bronze, and iron, mainly from near the surface

Scarabs and small plaques bearing Ethiopian and Egyptian cartouches ranging from about 700 B C, and numerous objects still under investigation

During the second season two cemeteries were excavated and a large number of graves opened, human remains of various other types being found in various postures, and many objects of interest obtained *in situ* Also animal burials, including cows

No objects from this site have been identified as of a date later than the Ptolemaic period Thus far everything of a datable nature has been found within 50 centimetres of the surface Stone implements and other primitive remains were mainly found below 50 centimetres

Stringent precautions were taken to ensure that every object, however minute, showing the handiwork of man, should be collected unimpaired and conserved for study

I am reserving all conclusions until the excavations are sufficiently complete to permit of comprehensive study, and to warrant the assumption that they are fully representative of the site

---

10. *Red Coloration on Ancient Bones from Nubia.* *By* Douglas E Derry, *M B , Ch B.*

At the International Congress of Anthropology and Archæology held at Monaco in 1896 a discussion took place on the subject of the red coloration occasionally found on bones in ancient graves Various views were advanced as to the reason of such staining, and the general opinion appeared to attribute it to burial of the body upon a bed of ochre, as this substance had been found in quantity in the graves A suggestion was also made that the body had been painted red before burial, or that the bones themselves were painted red after removal of the tissues, either naturally or by artificial means

During the progress of the work of the Archæological Survey in Nubia, several instances of the phenomenon which formed the subject of the above-mentioned discussion were met with Dr Wood Jones found in one grave two bodies upon whose bones a red pigment was deposited, which could easily be cleaned off He suggested that it was probably the only lasting traces of a coloured fabric which had lain in close contact with the body, and thought the pigment might be red hæmatite On chemical examination it proved to be 'an ochreous clay mixed with quartz grains' Bodies were also found lying upon and covered with matting composed of dried alfa-grass stems, the edges of which had been dyed red, and Mr A M Blackman, attached at that time to the same Expedition, describes a grave in which the body had apparently been wrapped in leather thickly impregnated with red pigment, the leather lying in quantities below the bones, though there were traces of it above as well Through the kindness of Mr C M Firth, head of the Archæological Survey, I am enabled to show samples both of the matting and also of the leather

In the following year I found in a grave of the Middle Nubian period, circa 2000 B C , a body of which the bones were coloured a deep brick-red tint From the distribution of the pigment it was clear that the colour was derived from a garment placed round the body *after* it had been flexed for burial, and some small lumps of red matter, much worm-eaten, which were found amongst the bones are almost certainly the remains of leather

Professor Elliot Smith has pointed out that it was the custom during the Twenty-first Dynasty in Egypt to paint the mummies of men with a material which chemical examination has shown to be a mixture of red ochre and gum

Thus all our Egyptian and Nubian cases lend no support to the hypothesis that red staining of bones is evidence of mutilation of the body before burial, but prove undoubtedly that the ochre was used as a pigment to colour grave clothes or the matting in which the bodies were sometimes wrapped

---

11 *An Egyptian Macrocephalic Skull, with the Bones of the Skeleton* *By* Douglas E Derry, *M B , Ch B*

A skeleton illustrating the above condition was found at Shurafa, near Heluan, on the East bank of the Nile, by Mr R Engelbach, working on behalf of the British School of Archæology, and the bones have been very kindly lent to the writer by Professor Flinders Petrie for examination and description

The remains are those of an adult man of small stature, but the skull is quite abnormal in size, its capacity being double that of an average British cranium, though it is apparent that the increase is almost entirely in the cranial vault, both face and base of skull being practically normal It exhibits a slight but definite asymmetry due to a bulging of the right parietal region, and the nose and face have a definite inclination to the left side

The great weight of the skull and brain have caused a flattening of the occipital condyles, and for the same reason the external occipital protuberance and superior curved line are unusually well marked in correspondence with the increased strain on the muscles attached thereto

The impressions of the cerebral convolutions on the inner surface of the parietal bones are larger and more distinctly marked than in a normal skull, pointing to considerable cerebral pressure which was probably greater on the right side, as shown by the bulging of the right parietal bone

This excessive pressure has influenced the development of the bones of the

left side of the body, owing in all probability to a partial paralysis of the muscles. All the left bones show this under-development In the femora the irregular distribution of the body weight, owing to the hemiplegia, has reacted upon the bones so that the contrast between the nearly normal right femur and the twisted and attenuated left bone is very striking The weight of the body being thrown chiefly on the right side has prevented the proper development of the left acetabulum which is shallow and irregularly shaped in correspondence with the head of the left femur

From the appearance of the sacrum it is certain that there was a marked lateral curvature of the spine

All the above facts point to the probability of there having been a left hemiplegia due to abnormal pressure on the motor centres of the right half of the brain, and the case is interesting both from the pathological and the anatomical sides, illustrating in the one the effect of muscular paralysis on the development of bones, and in the other suggesting a possible explanation of such facts as the difference in size of articular surfaces in the sexes, the torsion and flattening of bones, and the production of certain markings not hitherto recognised.

WEDNESDAY, SEPTEMBER 11.

The following Papers were read —

1. *Nubas Ancient and Modern.* *By* FREDERIC WOOD JONES, *D Sc., M B*

The Archæological Survey of Nubia undertaken by the Government of Egypt commenced its field work in 1907, and from that date until last year a continuous excavation of burial-grounds situated in the Nile Valley in Nubia has been carried out This expedition has yielded an enormous amount of material for the anthropological study of the inhabitants of Nubia from pre-dynastic times until the Christian period Much new light has been shed upon the Nubian population of pre-dynastic, early dynastic, Middle and New Empire days, and we have a fairly connected story of the race movements during this long period As breaks in this connected story we have some groups of burials which do not find a natural place in the sequence of types One such group was designated the 'X Group,' since both the type of burial and grave-furniture and the physical type of the dead presented certain anomalous features

These 'X group' people are dated on very definite archæological grounds to 200–500 A D they did not adopt the characteristic Christian type of burial, but were interred in 'side-chamber' graves, and their pottery forms were for the most part foreign to the culture of the surrounding peoples Their physical characteristics were not well defined when the first Annual Report of the Survey was published, since the intact remains of the people were altogether insufficient Since that date (1907–08) much new evidence has accrued Firstly, a good series of intact bodies has been found in the later field work of the expedition, and secondly, Captain R G Anderson, of the Egyptian Medical Corps, has discovered beyond the southern confines of Nubia graves of true 'X group' types containing bodies showing mutilations and physical characters similar to those of the 'X group' people Further, recent skulls have been obtained both by Captain Anderson and by Dr Seligmann which throw a great deal of new light upon the racial affinities of these intruders in early Christian times in Nubia

---

2 *The Lesions caused by Judicial Hanging An Anthropological Study* *By* FREDERIC WOOD JONES, *D Sc , M.B.*

During the first season's field-work of the Egyptian Government Survey of Nubia there was unearthed in the neighbourhood of Shellal a series of bodies, buried roughly in trenches, showing the effects of various forms of violent death. The physical type of these men—for all were adult males—indicated them to be

intrusions on the typical Egyptian population Their place of burial was within the walls of what had been a Roman frontier fort, and there was every indication that they had been executed in Roman times One man actually had the hangman's rope *in situ* round his neck, and a very large number showed a curious lesion of the base of the skull. This lesion was diagnosed in the field as being caused by hanging, and its method of production seemed clear However, when skulls of criminals were examined in museums it was found that this lesion did not exist in men known to have been 'hanged' Quite recently the skull of a man executed in 1865 has been described

The interest of the case lies in the fact that this skull shows the same lesions as are displayed by the men executed by the Romans in Nubia

Methods of hanging have changed from time to time, and the lesions produced have been studied by many people, but there is still a great want of agreement in the ideas as to the actual injury inflicted

It is probable that in the cases of this criminal and the Nubian men much the same methods were employed, but in the history of English judicial hanging the variation in method has easily accounted for the variety of lesions which have been found and claimed as *the* cause of death

The reason why *no* lesion is found in so many museum specimens is probably to be sought in this evolution of hanging 'Hanging' may imply (1) the hanging of a corpse, (2) the hanging (strangulation) of a living being, (3) or the dropping and hanging used to-day as the form of judicial death in England Each has its historical aspect and its anthropological and pathological interest

---

3. *Professor Reisner's Excavations in Egypt on behalf of the Boston Museum and Harvard University* *By* Professor G ELLIOT SMITH, *M A, M D, F R S.*

---

4. *The Temple of Philæ and the Archæological Survey of Nubia.* *By* F F. OGILVIE

---

5. *An Account of some Bontoc Igorots.* *By* L. F. TAYLOR, *B A.*

A party of fifty-four Bontoc Igorots (including thirty-six men, sixteen women, and two infants) has been exhibited at Earls Court in London during the last few weeks Permission to make measurements and observations was courteously given by Mr Schneiderwindt, who is in charge of the natives. The work was carried out by the author, under the direction of Dr Duckworth The photographs are the work of Mr K H Wang

The natives are genuine representatives of the tribe whose name they bear The Igorots of Bontoc are Indonesians, and it is supposed that they represent a comparatively unmixed subdivision of that widely distributed stock

The men are short (the mean stature being only 155 cm), but of almost ideal muscular development The skin is of a dark bronze-brown shade, the presence of a circle of small pigmented patches on the crown of the head of one infant is worth special mention, for it is alleged that these patches, though common in infancy, fade away subsequently

The hair is black or of the darkest brown, while plentiful and coarse on the scalp it is scanty elsewhere The women are much shorter than the men, and in appearance recall the Indo-Chinese The measurements provide indications of two groups in this community Of these, one appears to be early Indonesian, the other late Indonesian, or proto-Malay The conclusion is that the Bontoc Igorots represent an admixture of late Indonesians with the remnant of an early Indonesian population, the fusion being not yet complete The women do not provide the same amount of evidence of subdivision into groups as do the men. Among the Igorots of other parts are still to be found remnants of an early Caucasian population.

Among the other data collected, only the observations on the tattoo patterns, on the mode of climbing, as well as some relating to the arts and crafts exhibited by these natives, can be mentioned here.

A set of photographic prints will be presented to the Royal Anthropological Institute The detailed descriptions, together with the averages and indices based on the numerical data, are nearly ready for publication, which will be undertaken as soon as possible.

---

6 *On a Totem-pole from the Queen Charlotte Islands.* *By* Miss B Lindsay

One of the totem-poles of the Haida Indians, hitherto undescribed, was sent from Victoria in the year 1890, by the late Mr Arthur More, of the Bank of British Columbia The pole is a small one, carved in stone, the material being a hard black shale The back of the pole is slightly hollowed

The five sculptured figures are of beautiful workmanship The lowest one represents the Bear Totem The next, a bird with an enormous beak, represents the Raven Totem The middle figure represents the conventional Beaver Totem, the tail is marked with a scale-like pattern of diagonal lines The paws of the figure, placed on each side of the mouth, are holding a stick at which the animal is gnawing The penultimate figure is human It has no legs, but two paw-like hands are squeezed under the chin The perforated nose appears as if drawn downwards to the level of the upper teeth The top figure represents the porcupine, the quills being indicated by long depressed scratches on the stone The characteristic attitude of the rodent head has been cleverly indicated by the sculptor

The measurements are approximately as follows —Height, 17½ inches, width, at base 3 inches, at top 2 inches, projection of lowest figure 3 inches, of top figure nearly 2 inches A small separate slab of the same stone, the outer face of which is rounded and polished, serves as a base for the pole

---

7 *Note on the Living Representatives of the Old North-Eastern Asiatic Race which gave America its Indians* *By* Dr Aleš Hrdlička

---

8 *The Establishment and First Year and a Half's Work of the Anthropological Division of the Geological Survey of Canada* *By* Dr George Bryce

The Anthropological Division of the Geological Survey was organised on September 1, 1910, under the direction of a regularly appointed Government staff consisting of Dr E Sapir, Mr C M Barbeau, and Mr Harlan I Smith The Department was divided into three branches Ethnology and Philology, Archæology, and Physical Anthropology As a rule the special expeditions and local surveys have been entrusted to paid agents not on the permanent staff

The following is a brief sketch of the work which has already been done —

Dr Sapir has been engaged in both museum and field work In the museum the accumulated material has been unpacked and sorted out according to class (physical, ethnological, and archæological), and according to the five Canadian Indian culture areas In the field Dr Sapir has been engaged in the investigation of the Nootka of Vancouver Island, and in a number of preliminary surveys of the Indians of Ontario and Quebec

Mr Barbeau was sent to work among the Hurons and Wyandots, his investigations of their social organisation have proved fertile of results, which have, however, been surpassed by the results of his survey of their technology

Mr H I Smith's acquaintance with British Columbia, and experience in museum work, have been utilised in the collection and arrangement of specimens from that area He has been assisted in the museum work by Dr Wintemberg

Mr V Stefansson, who is acting as joint agent of the Natural History Museum New York, and the Canadian Survey, is engaged in Arctic exploration In 1910 he discovered a hitherto undescribed people near Cape Bixley

Collections of folklore and legends of the Micmacs of eastern Canada have been made by Dr C MacMillan, who has also recorded his observations of birth,

marriage, and funeral customs, occupations and industries, games and social organisation.

Dr. A. Goldenweiser spent two months of the summer of 1911 on the Iroquois Reserve at Tuscarora, Brant Co , Ontario He obtained much important information as to the social organisation of the Iroquois natives

Mr F. W. Waugh and Mr F H S Knowles are also working among the Iroquois on the Six Nations Reserve near Brantwood

Linguistic work among the Ojibway is being carried on by Dr P Radin Dr. W. H Mechlin has obtained much valuable information as to the sociology, religion, and linguistics of the Malecite and Micmac tribes of New Brunswick and Quebec. He has also secured a valuable collection of phonograph records and specimens illustrating Indian life and culture

Mr J. A Teit will begin work on the distribution and classification of the Athabascan tribes during the coming year.

The Department is working with vigour to cover the whole Canadian field, and it is hoped that at the end of another year, when the arrangement of the collections already made has been completed, Canada will be fully in line with other countries

9. *Prehistoric Remains in the Upper Stort Valley*[1] *By the* Rev A Irving, *D Sc* , *B A*

During the year 1912 remains have turned up in excavations in three new localities —

(i.) *At Maple Avenue* (not far from the spot where the horse skeleton was found),[2] including remains of

(1) *Horse* two broken *metacarpals* comparable with those found last year beneath the Stort alluvium

(2) *Ox* one *radius* (upper half), two *tibiæ* (upper half), one ground flat and perforated as the 'haft'[3] for a wedge-shaped flint axe; *metacarpal* (lower half), two *metatarsals* (one nearly complete, but gnawed at the lower end), one *tibia* (lower half), one *humerus* (lower end)

(3) *Sheep* broken mandible (a large animal)

(4) *Human artefacts* five or six worked flints, including two borers (? one and a scraper), two fragments of coarse neolithic pottery

Several of the bones show marks of teeth of some carnivorous animal, and two bear marks (at the fracture) of a hatchet (suggesting the Bronze Age) They were found on the hill-slope under 1½ to 2 feet of 'rubble drift' (clay and humus soil), the excavation being carried down into the solid London Clay

(ii) *Site of new post office in South Street*.—Excavation (some 8 feet deep) in 'rubble-drift' material, mostly *remanié* stuff from the Boulder Clay which caps the hill, above The materials showed a feeble stratification in general concordance with the hill-slope Several broken antlers of *Cervus elaphus* (perforated and otherwise worked) were found in it

(iii) *Henham* (see *Nature*, May 2, 1912).

Note —Observations by Mr P A Irving, B A , on the face of an extensive gravel-pit at Thorley during the British Association Meeting at Dundee have led to the opening-up of a prehistoric site, with pottery (of several types), flint implements, charcoal, fire-stones, bones, and teeth of *Equus*, *Bos*, *Sus*, and *Castor* (?). Several of the 'finds' are of special interest, including a decayed mandible with *pm.* 1, *pm* 2, *pm* 3, *pm* , and *m* 1 4 all in place, which, by measurements, must have belonged to a horse of a bigger type than the Stortford-Grimaldi horse; also a nearly complete 'tulip-shaped' beaker or drinking-cup 3½ inches high (October 1912)

[1] See *Brit Assoc Reports* (Section H), Sheffield, 1910, and Portsmouth, 1911.
[2] *Ibid* 1910, pp 616 and 736.
[3] Cf. B M *Guide to the Stone Age*, p. 70.

10. *On the Discovery of a Neolithic Cemetery at La Motte, Jersey.*[1] *By* R. R. Marett, *M.A.*

Owing in part to observations and suggestions made by some of the members of the British Association who visited the archæological sites of Jersey last year, at the close of the Portsmouth Meeting, it was resolved by the Société Jersiaise to excavate the islet of La Motte, which lies a few hundred yards away from the mainland at the western horn of St. Clement's Bay. The shape and geological formation of this islet may be roughly described as follows. It divides into an eastern and western portion joined by a narrow neck, and consists of a basement of diorite, overlaid by about 12 feet of loess, which in turn is capped by another 12 feet of more or less sandy soil. Deep down in the loess a human cranium had been found in 1861; higher up, at the junction of the loess with the lighter soil, neolithic implements had occasionally been discovered in the almost vertical sides of the island; finally, in the course of last year, small landslips on the south side of the western portion had revealed cist-like structures at the border-line between the loess and the upper stratum. Excavations begun in October 1911 and completed in April 1912 soon made it clear that the cist-like structures belonged to graves, built of largish unhewn blocks of the local diorite, with their flattest sides inwards, and covered with broad capstones. Eleven of these graves were from 5 feet 6 inches to 6 feet long. Four others were much shorter, one being a mere casket constructed of four blocks covered by a capstone a foot long. The function of the longer graves was apparent from one in which enough of the skeleton remained to show it to be a crouched burial. In the smaller ones, unfortunately, the bone was in the last stage of disintegration, so that it was impossible to say whether these were the graves of children, or cists designed to contain a packet of bones the result of pre-sepulchral decarnation. Three skulls in all proved more or less measurable, one only being well preserved. Their cranial indices were respectively 69.6, 72.6, and 73.9, thus displaying uniform dolichocephaly. The artefacts found in the graves were of poor quality, consisting of celts that were merely pebbles of shale with a ground edge, and sherds of coarse pottery, mostly without pattern.

The eastern half of the islet turned out to be the site of a large cairn, furnished on one side with a supporting wall. Bone detritus was apparent at almost every point beneath it, and the same sort of rude stone implements and potsherds underlay it here and there.

At one place in the western half of the islet, and at several in the eastern half, especially on the north-eastern side of the cairn, kitchen middens were discovered containing a large quantity of charcoal, numerous limpet shells, mostly calcined, and bones of ox, pig, and a small variety of sheep. There was also a fragment which seemed part of a human ulna. Potsherds were common, and these, unlike those in the graves, were frequently ornamented with incised patterns of a simple kind. Their faces were decidedly neolithic, being comparable to that of pottery found in the neighbouring dolmen of Mont Ubé. As the middens overlaid the cairn in places, there was reason to think that they might belong to a somewhat later date.

The presence of a neolithic cemetery on the upper surface of the loess makes it probable that the skull found deeply imbedded in it (the cranial index of which is approximately 75.6) is not coeval with the loess, and hence pleistocene, as was hitherto thought, but has somehow slipped down from above.

An interesting question of geology is how to account for the deposition of 12 feet of æolian soil above the neolithic floor. If land and sea stood in their present relation to each other this accumulation could not possibly take place, the wind nowadays causing the island to lose far more sand than it gains. It would seem that La Motte was part of the mainland both during the time when neolithic man used it as a burial-ground, and long enough after for wind-borne materials to form a deep drift over it.

[1] To be published in full in *Archæologia.*

SECTION I.—PHYSIOLOGY.

PRESIDENT OF THE SECTION.—LEONARD HILL, M.B., F.R.S.

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

LAST year the distinguished President of this Section raised us to the contemplation of the workings of the soul. I ask you to accompany me in the consideration of nothing higher than a stuffy room. Everyone thinks that he suffers in an ill-ventilated room owing to some change in the chemical quality of the air, be it want of oxygen, or excess of carbon dioxide, the addition of some exhaled organic poison, or the destruction of some subtle property by passage of the air over steam-coils, or other heating or conducting apparatus. We hear of 'devitalised' or 'dead' air, and of 'tinned' or 'potted' air of the battleship. The good effects of open-air treatment, sea and mountain air, are no less generally ascribed to the chemical purity of the air. In reality the health-giving properties are those of temperature, light, movement, and relative moisture of the surrounding atmosphere, and leaving on one side those gross chemical impurities which arise in mines and in some manufacturing processes, and the question of bacterial infection, the alterations in chemical composition of the air in buildings where people crowd together and suffer from the effects of ill-ventilation have nothing to do with the causation of these effects.

Satisfied with the maintenance of a specious standard of chemical purity, the public has acquiesced in the elevation of sky scrapers and the sinking of cavernous places of business. Many have thus become cave-dwellers, confined for most of their waking and sleeping hours in windless places, artificially lit, monotonously warmed. The sun is cut off by the shadow of tall buildings and by smoke—the sun, the energiser of the world, the giver of all things which bring joy to the heart of man, the fitting object of worship of our forefathers.

The ventilating and heating engineer hitherto has followed a great illusion in thinking that the main objects to be attained in our dwellings and places of business are chemical purity of the air and a uniform draughtless summer temperature.

Life is the reaction of the living substance to the ceaseless play of the environment. Biotic energy arises from the transformation of those other forms of energy—heat, light, sound, &c.—which beat upon the transformer—the living substance (B. Moore). Thus, when all the avenues of sense are closed, the central nervous system is no longer aroused and consciousness lapses. A boy, paralysed in almost all his avenues of sense, fell asleep whenever his remaining eye was closed. The patient who lost one labyrinth by disease and, to escape unendurable vertigo, had the other removed by operation, was quite unable to guide his movements or realise his position in the dark. Rising from bed one night, he collapsed on the floor and remained there helpless till succour arrived.

A sense organ is not stimulated unless there is a change of rate in the transference of energy; and this to be effectual must occur in most cases with considerable quickness If a weak agent is to stimulate, its application must be abrupt (Sherrington) Thus the slow changes of barometric pressure on the body-surface originate no skin sensations, though such changes of pressure, if applied suddenly, are much above the threshold value for touch A touch excited by constant mechanical pressure of slight intensity fades quickly below the threshold of sensation Thus the almost unbearable discomfort which a child feels on putting on for the first time a 'natural' wool vest fades away, and is no longer noticed with continual wear Thomas à Beckett soon must have become oblivious to his hair-shirt, and even to its harbingers It is not the wind which God tempers to the shorn lamb, but the skin of the lamb to the wind The inflow of sensations keeps us active and alive and all the organs working in their appointed functions The cutaneous sensations are of the highest importance The salt and sand of wind-driven sea air particularly act on the skin and through it braces the whole body The changing play of wind, of light, cold, and warmth stimulate the activity and health of mind and body Monotony of sedentary occupation and of an overwarm still atmosphere endured for long working hours destroys vigour and happiness and brings about the atrophy of disuse We hear a great deal of the degeneration of the race brought about by city life, but observation shows us that a drayman, navvy, or policeman can live in London, or other big city, strong and vigorous, and no less so than in the country The brain-worker, too, can keep himself perfectly fit if his hours of sedentary employment are not too long and he balances these by open-air exercise The horses stabled, worked, and fed in London are as fine as any in the world; they do not live in windless rooms heated by radiators

The hardy men of the North were evolved to stand the vagaries of climate—cold and warmth—a starved or full belly have been their changing lot The full belly and the warm sun have expanded them in lazy comfort, the cold and the starvation have braced them to action Modern civilisation has withdrawn many of us from the struggle with the rigours of Nature, we seek for and mostly obtain the comfort of a full belly and expand all the time in the warm atmosphere afforded us by clothes, wind-protected dwellings, and artificial heat—particularly so in the winter, when the health of the business man deteriorates Cold is not comfortable, neither is hunger, therefore we are led to ascribe many of our ills to exposure to cold, and seek to make ourselves strong by what is termed good living I maintain that the bracing effect of cold is of supreme importance to health and happiness, that we become soft and flabby and less resistant to the attacks of infecting bacteria in the winter not because of the cold but because of our excessive precautions to preserve ourselves from cold; that the prime cause of 'cold' or 'chill' is not really exposure to cold but to the over-heated and confined air of rooms, factories, and meeting-places Seven hundred and eleven survivors were saved from the *Titanic* after hours of exposure to cold Many were insufficiently clad and others wet to the skin Only one died after reaching the *Carpathia*, and he three hours after being picked up Those who died perished from actual cooling of the body Exposure to cold did not cause in the survivors the diseases commonly attributed to cold

Conditions of city and factory life diminish the physical and nervous energy, and reduce many from the vigorous health and perfectness of bodily functions which a wild animal possesses to a more secure, but poorer and far less happy, form of existence The ill chosen diet, the monotony and sedentary nature of daily work, the windless uniformity of atmosphere, above all, the neglect of vigorous muscular exercise in the open air and exposure to the winds and light of heaven—all these, together with the difficulties in the way of living a normal sexual life, go to make the pale, undeveloped, neurotic, and joyless citizen Nurture in unnatural surroundings, not Nature's birth-mark, moulds the criminal and the wastrel The environment of childhood and youth is at fault rather than the stock, the children who are taken away and trained to be sailors, those sent to agricultural pursuits in the Colonies, those who become soldiers, may develop a physique and bodily health and vigour in striking contrast to their brothers who become clerks, shop assistants, and compositors.

Too much stress cannot be put on the importance of muscular exercise in

regard to health, beauty, and happiness Each muscle fills with blood as it relaxes, and expels this blood on past the venous valves during contraction. Each muscle together with the venous valves forms a pump to the circulatory system It is the function of the heart to deliver the blood to the capillaries, and the function of the muscles—visceral, respiratory, and skeletal—to bring it back to the heart. The circulation is contrived for a restless mobile animal; every vessel is arranged so that muscular movement furthers the flow of blood.

The pressure of the blood in the veins and arteries under the influence of gravity varies with every change of posture The respiratory pump, too, has a profound influence on the circulation. Active exercise, such as is taken in a game of football, entails endless changes of posture, varying compressive actions—one with another struggling in the rough and tumble of the game—forcible contractions and relaxations of the muscles, and a vastly increased pulmonary ventilation, at the same time the heart's action is accelerated and augmented and the arterial supply controlled by the vaso-motor system The influence of gravity, which tends to cause the fluids of the body to sink into the lower parts, is counteracted, the liver is rhythmically squeezed like a sponge by the powerful respiratory movements, which not only pump the blood through the abdominal viscera but thoroughly massage these organs, and kneading these with the omentum clean the peritoneal cavity and prevent constipation At the same time the surplus food metabolic products, such as sugar and fat, stored in the liver, are consumed in the production of energy, and the organs swept with a rapid stream of blood containing other products of muscular metabolism which are necessary to the inter-relation of chemical action The output of energy is increased very greatly, a resting man may expend two thousand calories per diem, one bicycling hard for most of the day expended eight thousand calories, of which only four thousand were covered by the food eaten

Such figures show how fat is taken off from the body by exercise, for the other four thousand calories come from the consumption of surplus food products stored in the tissues While resting a man breathes some seven litres of air, and uses 300 c c of oxygen per minute, against 140 litres and 3000 c c while doing very hard labour. The call of the muscles for oxygen through such waste products as lactic acid impels the formation of red corpuscles and hæmoglobin. The products of muscular metabolism in other ways not yet fully defined modify the metabolism of the whole body.

Exposure to cold, cold baths, and cold winds has a like effect, accelerating the heart and increasing the heat production, the activity of the muscles, the output of energy, the pulmonary ventilation, and intake of oxygen and food In contrast with the soft pot-bellied, over-fed city man the hard, wiry fisherman trained to endurance has no superfluity of fat or tissue fluid His blood volume has a high relative value in proportion to the mass of his body His superficial veins are confined between a taut skin and muscles, hard as in a race-horse trained to perfection Thus the adequacy of the cutaneous circulation and loss of heat by radiation rather than by sweating is assured His fat is of a higher melting-point, hardened by exposure to cold In him less blood is derived to other parts such as adipose tissue, skin, and viscera He uses up the oxygen in the arterial blood more completely and with greater efficiency, for the output of each unit of energy his heart has to circulate much less blood (Kreogh), his blood is sent in full volume by the well-balanced activity of his vaso-motor system to the moving parts Owing to the perfect co-ordination of his muscles, trained to the work, and the efficient action of his skin and cutaneous circulation—the radiator of the body—he performs the work with far greater economy and less fatigue The untrained man may obtain 12 per cent of his energy output as work, against 30 per cent or perhaps even 50 per cent obtained by the trained athlete Hence the failure and risk suffered by the city man who rushes straight from his office to climb the Alps On the other hand, the energetic man of business or brain worker is kept by his work in a state of nervous tension He considers alternative lines of action, but scarcely moves He may be intensely excited, but the natural muscular response does not follow. His heart is accelerated and his blood pressure raised, but neither muscular movements and accompanying changes of posture, nor the respiratory pump materially aid the circulation. The activity of his brain

demands a rapid flow of blood, and his heart has to do the circulatory work, as he sits still or stands at his desk, against the influence of gravity. Hence a high blood pressure is maintained for long periods at a time by vaso-constriction of the arteries in the lower parts of the body and increased action of the heart; hence, perhaps, arise those degenerative changes in the circulatory system which affect some men tireless in their mental activity. We know that the bench-worker, who stands on one leg for long hours a day, may suffer from degeneration and varicosity of the veins in that leg. Long continued high arterial pressure, with systolic and diastolic pressures approximately the same, entails a stretched arterial wall, and this must impede the circulation in the vaso vasorum, the flow of tissue lymph in, and nutrition of, the wall Since his sedentary occupation reduces the metabolism and heat production of his body very greatly, the business man requires a warmer atmosphere to work in If the atmosphere is too warm it reduces his metabolism and pulmonary ventilation still further · thus he works in a vicious circle Exhausting work causes the consumption of certain active principles, for example, adrenin, and the reparation of those must be from the food. To acquire certain of the rarer principles expended in the manifestation of nervous energy more food may have to be eaten by the sedentary worker than can be digested and metabolised His digestive organs lack the kneading and massage, the rapid circulation and oxidation of foodstuffs which is given by muscular exercise Hence arise the digestive and metabolic ailments so common to brain workers

Mr. Robert Milne informs me that of the thousands of children which have passed through Barnardo's Homes—there are 9,000 in the homes at any one time—not one after entering the institution and passing under its regimen and the care of his father, Dr Milne, has developed appendicitis Daily exercise and play, adequate rest, a regular simple diet have ensured their immunity from this infection It pays to keep a horse healthy and efficient, it no less pays to keep men healthy I recently investigated the case of clerks employed in a great place of business, whose working hours are from 9 to 6 on three days, and 7 to 9 on the other three days of each week, and, working such overtime, they make *1l* to *2l* a week, these clerks worked in a confined space—forty to fifty of them in 8,200 cubic feet, lit with thirty electric lamps, cramped for room, and overheated in warm summer days It is not with the chemical purity of the air of such an office that fault is to be found, for fans and large openings ensured this sufficiently These clerks suffered from their long hours of monotonous and sedentary occupation, and from the artificial light, and the windless, overwarm and moist atmosphere Many a girl cashier has worked from 8 to 8 30, and on Saturdays from 8 to 10, and then has had to balance her books and leave perhaps after midnight on Sunday morning Her office is away in the background—confined, windless, artificially lit The Shops Act has given a little relief from these hours What, I ask, is the use of the State spending a million a year on sanatoria and tuberculin dispensaries, when those very conditions of work continue which lessen the immunity and increase the infection of the workers?

The jute industry in this town of Dundee is carried out almost wholly by female and boy labour 'The average wages for women are below 12*s* in eight processes, and above 12*s*, but under 18*s*, for the remaining five processes' The infant mortality has been over 170 per 1,000 The Social Union of Dundee reported in 1905 that of 885 children born to 240 working mothers no fewer than 520, or 59 per cent, died—and almost all of them were under five years of age The life of these mothers was divided between the jute factory and the one-roomed tenement Looking such conditions squarely in the face, I say it would be more humane for the State to legalise the exposure of every other new-born infant on the hillside rather than allow children to be slowly done to death The conditions, as given in the Report, contravene those rights of motherhood which the meanest wild animal can claim

Isolation hospitals, sputum-pots, and anti-spitting regulations will not stamp out tuberculosis Such means are like shutting the door of the stable when the horse has escaped. Flügge has shown that tubercle bacilli are spread by the droplets of saliva which are carried out as an invisible spray when we speak, sing, cough, sneeze Sputum-pots cannot control this The saliva of cases of phthisis may teem with the bacilli The tuberculin reaction tests carried out

by Hamburger and Monti in Vienna show that 94 per cent of all children aged eleven to fourteen have been infected with tubercle In most the infection is a mere temporary indisposition I believe that the conditions of exhausting work, and amusement in confined and overheated atmospheres, together with ill-regulated feeding, determine largely whether the infection, which almost none can escape, become serious or not Karl Pearson suggests that the death statistics afford no proof of the utility of sanatoria or tuberculin dispensaries, for during the very years in which such treatment has been in vogue the fall in the mortality from tuberculosis has become less relatively to the fall in general mortality He opines that the race is gradually becoming immune to tubercle, and hence the declination in the mortality curve is becoming flattened out —that Nature is paramount as the determinant of tuberculosis, not nurture From a statistical inquiry into the incidence of tuberculosis in husband and wife and parent and child Pearson concludes that exposure to infection as in married couples is of little importance, while inborn immunity or diathesis is a chief determinant Admitting the value of his critical inquiries and the importance of diathesis, I would point out that in the last few years the rush and excitement of modern city life has increased, together with the confinement of workers to sedentary occupations in artificially lit, warm, windless atmospheres The same conditions pertain to places of amusement eating-houses, tube railways, &c

Central heating, gas-radiators, and other contrivances are now displacing the old open fire and chimney This change greatly improves the economical consumption of coal and the light and cleanliness of the atmosphere But in so far as it promotes monotonous, windless, warm atmospheres, it is wholly against the health and vigour of the nation The open fire and wide chimney ensure ventilation, the indrawing of cold outside air, streaky air—restless currents at different temperatures, which strike the sensory nerves in the skin and prevent monotony and weariness of spirit By the old open fires we were heated with radiant heat The air in the rooms was drawn in cool and varied in temperature The radiator and hot-air system give us a deadly uniformly heated air—the very conditions we find most unsupportable on a close summer's day

In Labrador and Newfoundland, Dr Wakefield tells me, the mortality of the fisherfolk from tuberculosis is very heavy It is generally acknowledged to be four per 1,000 of the population per annum, against 1 52 for England and Wales Some of the Labrador doctors talk of seven and even eight per 1,000 in certain districts The general death rate is a low one The fishermen fish off shore, work for many hours a day in the fishing season, and live with their families on shore in one-roomed shanties These shanties are built of wood, the crannies are 'stogged' with moss, and the windows nailed up, so that ventilation is very imperfect They are heated by stoves and kept at a very high temperature, *e g*, 80° F Outside in the winter the temperature may be 30 degrees below freezing The women stay inside the shanties almost all their time, and the tuberculosis rate is somewhat higher in them The main food is white bread, tea stewed in the pot till black, fish occasionally, a little margarine and molasses The fish is boiled and the water thrown away Game has become scarce in recent years, old, dark-coloured flour—spoken of with disfavour—has been replaced by white flour In consequence of this diet beri-beri has become rife to a most serious extent, and the hospitals are full of cases Martin Flack and I have found by our feeding experiments that rats, mice, and pigeons cannot be maintained on white bread and water, but can live on wholemeal, or on white bread in which we incorporate an extract of the sharps and bran in sufficient amount Recent work has shown the vital importance of certain active principles present in the outer layers of wheat, rice, &c, and in milk, meat, &c, which are destroyed by heating to 120° C A diet of white bread or polished rice and tinned food sterilised by heat is the cause of beri-beri The metabolism is endangered by the artificial methods of treating foods now in vogue As to the prevalency of tuberculosis in Labrador, we have to consider the intermarriage, the bad diet, the over-rigorous work of the fishermen, the overheating of, and infection in the shanties Dr Wakefield has slept with four other travellers in a shanty with father, mother, and ten children In some there is scarce room on the floor to lie down The shanties are heated with a stove on which pots boil all the time, water runs down the windows The

patients are ignorant, and spit everywhere, on bed, floor, and walls In the schools the heat and smell is most marked to one coming in from the outside air In one school 50 cubic feet per child is the allowance of space The children are eating all day long, and are kept in close hot confinement They suffer very badly from decay of the teeth Whole families are swept off with tuberculosis, and the child who leaves home early may escape, while the rest of a family dies Here, then, we have people living in the wildest and least populated of lands with the purest atmosphere suffering from all those ill-results which are found in the worst city slums—tuberculosis, beri-beri, and decayed teeth

The bad diet probably impels the people to conserve their body heat and live in the over-warm, confined atmosphere, just as our pigeons fed on white bread sit, with their feathers out, huddled together to keep each other warm

The metabolism, circulation, respiration, and expansion of the lung are all reduced. The warm, moist atmosphere lessens the evaporation from the respiratory tract, and therefore the transudation of tissue lymph and activity of the ciliated epithelium The unexpanded parts of the lung are not swept with blood Everything favours a lodgment of the bacilli, and lessens the defences on which immunity depends In the mouth, too, the immune properties of the saliva are neutralised by the continual presence of food, and the temperature of the mouth is kept at a higher level, which favours bacterial growth Lieutenant Siem informs me that recently in Northern Norway there has been the same notable increase in tuberculosis The old cottage fireplaces with wide chimneys have been replaced with American stoves. In olden days most of the heat went up the chimney, and the people were warmed by radiant heat Now the room is heated to a uniform moist heat The Norwegians nail up the windows and never open them during the winter At Lofoten, the great fishing centre, motor-boats have replaced the old open sailing and row boats The cabin in the motor-boat is very confined, covered in with watertight deck, heated by the engine, crowded with six to eight workers When in harbour the fishermen used to occupy ill-fitted shanties, through which the wind blew freely, now, to save rent, they sleep in the motor-boat cabins

Here, again, we have massive infection, and the reduction of the defensive mechanisms by the influence of the warm, moist atmosphere

The Norwegian fishermen feed on brown bread, boiled fish, salt mutton, margarine, and drink, when in money, beer and schnapps, there is no gross deficiency in diet, as in Labrador, and beri-beri does not attack them They return home to their villages and longshore fishing when the season is over The one new condition which is common to the two districts is confinement in stove-heated, windless atmospheres In old days the men were crowded together, but in open boats or in draughty shanties, and had nothing but little cooking-stoves

The conditions of great cities tend to confine the worker in the office all day, and to the heated atmosphere of club, cinema show, or music-hall in the evening The height of houses prevents the town dweller from being blown upon by the wind, and, missing the exhilarating stimulus of the cool, moving air, he repels the dull uniformity of existence by tobacco and by alcohol, or by indulgence in food, *e g*, sweets, which are everywhere to his hand, and by the nervous excitement of business and amusement He works, he eats, and is amused in warm, windless atmospheres, and suffers from a feeble circulation, a shallow respiration, a disordered digestion, and a slow rate of metabolism

Many of the employments of modern days are detestable in their long hours of confinement and monotony Men go up and down in a lift all day, and girls in the bloom of youth are set down in tobacco stalls in underground stations, and their health and beauty there fade while even the blow-flies are free to bask in the sun In factories the operatives feed machines, or reproduce the same small piece of an article day after day There is no art, or change, no pleasure in contrivance and accomplishment The miner, the fisherman, even the sewerman, face difficulties, changing risks, and are developed as men of character and strength. Contrast the sailor with the steward on a steamer, the drayman outside with the clerk inside who checks the goods delivered at some city office, the butcher and the tailor, the seamstress and the market woman, and one sees the enormous difference which a confined occupation makes Monotonous sedentary employment makes for unhappiness because the inherited functional needs

of the human body are neglected, and education—when the outside field of interest is narrowed—intensifies the sensitivity to the bodily conditions The sensations arising within the body—proprioceptive sensations—come to have too large a share in consciousness in comparison with exteroceptive In place of considering the lilies how they grow, or musing on the beauty and motions of the heavenly bodies, the sedentary worker in the smoke-befouled atmosphere, with the limited activity and horizon of an office and a disturbed digestion, tends to become confined to the inward consideration of his own viscera and their motions.

Many of the educated daughters of the well-to-do are no less confined at home; they are the flotsam and jetsam cast up from the tide in which all others struggle for existence—their lives are no less monotonous than the sweated sempstress or clerk. They become filled with 'vapours' and some seek excitement not in the cannon's mouth but in breaking windows, playing with fire, and hunger strikes The dull monotony of idle social functions, shopping and amusement no less than that of sedentary work and an asexual life, impels to a simulated struggle—a theatrical performance, the parts of which are studied from the historical romances of revolution Each man, woman, and child in the world must find the wherewithal for living, food, raiment, warmth, and housing, or must die or get some other to find it for him It seems to me as if the world is conducted as if ten men were on an island—a microcosm—and five sought for the necessaries of life, hunted for food, built shelters and fires, made clothes of skins, while the other five strung necklaces of shells, made loin-cloths of butterfly wings, gambled with knuckle-bones, drew comic pictures in the sand, or carved out of clay frightening demons, and so beguiled from the first five the larger share of their wealth In this land of factories, while the many are confined to mean streets and wretched houses, possessing no sufficiency of baths and clean clothing, and are ill-fed, they work all day long, not to fashion for themselves better houses and clothing, but to make those unnecessaries such as 'the fluff' of women's apparel, and a thousand trifles which relieve the monotony of the idle and bemuse their own minds

The discovery of radium and its disintegration as a source of energy has enabled the physicist to extend Lord Kelvin's estimate of the world's age from some thirty to a thousand million years. Arthur Keith does not hesitate to give a million of these years to man's evolution Karl Pearson speaks of hundreds of thousands of years The form of the human skull, the brain capacity of man, his skill as evidenced by stone implements and cave drawings of animals in action, was the same tens of thousands of years ago as now For ages primitive man lived as a wild animal in tropical climes, discovered how to make fire, clothe himself in skins, build shelters, and so enable himself to wander over the temperate and arctic zones Finally, in the last few score of years, he has made houses draughtless with glass windows, fitted them with stoves and radiators, and every kind of device to protect himself from cold, while he occupies himself in the sedentary pursuits and amusements of a city life How much better, to those who know the boundless horizon of life, to be a frontiers-man and enjoy the struggle, with body hardened, perfectly fit, attuned to Nature, than to be a cashier condemned to the occupation of a sunless, windless pay-box The city child, however, nurtured and educated in confinement, knows not the largeness and wonders of Nature, is used to the streets with their ceaseless movement and romantic play of artificial light after dark, and does not need the commiseration of the country mouse any more than the beetle who lives in the dark and animated burrows of his heap But while outdoor work disciplines the body of the countryman into health, the town man needs the conscious attention and acquired educated control of his life to give him any full measure of health and happiness

Experimental evidence is strongly in favour of my argument that the chemical purity of the air is of no importance Analyses show that the oxygen in the worst-ventilated school-room, chapel, or theatre is never lessened by more than one per cent of an atmosphere, the ventilation through chink and cranny, chimney, door, and window, and the porous brick wall, suffices to prevent a greater diminution. So long as there is present a partial pressure of oxygen sufficient to change

the hæmoglobin of the venous blood into oxyhæmoglobin there can arise no lack of oxygen

At sea-level the pressure of oxygen in the pulmonary alveolar air is about 100 mm Hg Exposed to only half this pressure the hæmoglobin is more than 80 per cent saturated with oxygen

In noted health-resorts of the Swiss mountains the barometer stands at such a height that the concentration of oxygen is far less than in the more ventilated room On the high plateau of the Andes there are great cities · Potosi with a hundred thousand inhabitants is at 4,165 metres, and the partial pressure of oxygen there is about 13 per cent of an atmosphere in place of 21 per cent at sea-level, railways and mines have been worked up to altitudes of 14,000 to 15,000 feet At Potosi girls dance half the night, and toreadors display their skill in the ring On the slopes of the Himalayas shepherds take their flocks to altitudes of 18,000 feet No disturbance is felt by the inhabitants or those who reach these great altitudes slowly and by easy stages The only disability to a normal man is diminished power for severe exertion, but a greater risk arises from want of oxygen to cases of heart disease, pneumonia, and in chloroform anæsthesia at these high altitudes The newcomer who is carried by the railway in a few hours to the top of Pike's Peak or the Andes may suffer severely from mountain sickness, especially on exertion, and the cause of this is want of oxygen Acclimatisation is brought about in a few days' time The pulmonary ventilation increases, the bronchial tubes dilate, the circulation becomes more rapid The increased pulmonary ventilation lowers the partial pressure of carbon dioxide in the blood and pulmonary air, and this contributes to the maintenance of an adequate partial pressure of oxygen Haldane and Douglas say that the percentage of red corpuscles and total quantity of the hæmoglobin increases, and maintain that the oxygen is actively secreted by the lung into the blood, but the CO method by which their determinations have been made has not met with unqualified acceptance If waste products, which arise from oxygen want, alter the combining power of hæmoglobin, this alteration may not persist in shed blood, for these products may disappear when the blood is exposed to air Owing to the combining power of hæmoglobin the respiratory exchange and metabolism of an animal within wide limits is independent of the partial pressure of oxygen On the other hand, the process of combustion is dependent not on the pressure but on the percentage of oxygen Thus the aeroplanist may become seized with altitude sickness from oxygen want, while his gas engine continues to carry him to loftier heights

The partial pressure of oxygen in a mine at a depth of 3,000 feet is considerably higher than at sea-level and if the percentage is reduced to 17, while the firing of fire-damp and coal dust is impossible, there need be in the alveolar air of the lungs no lower pressure of oxygen than at sea-level Thus the simplest method of preventing explosions in coal mines is that proposed by J Harger, viz , to ventilate them with air containing 17 per cent of oxygen [1] There is little doubt that all the great mine-explosions have been caused by the enforcement of a high degree of chemical purity of the air In the old days when ventilation was bad there were no great dust explosions Mr W H Chambers, general manager of the Cadeby mine, where the recent disastrous explosion occurred, with the authority of his great and long practical experience of fiery mines, told me that the spontaneous combustion of coal and the danger of explosion can be wholly met by adequate diminution in ventilation. The fires can be choked out while the miners can still breathe and work The Coal Mines Regulation Act enforces that a place shall not be in a fit state for working or passing therein, if the air contains either less than 19 per cent of oxygen, or more than 1¼ per cent of carbon dioxide A mine liable to spontaneous combustion of coal may be exempted from this regulation by order of the Secretary of State

The regulations impel the provision of such a ventilation current that the percentage of oxygen is sufficient for the spread of dust explosions along the intake airways, with the disastrous results so frequently recorded If the mine were ventilated with air containing 17 per cent of oxygen in sufficient volume to keep the miners cool and fresh, not only would explosions be prevented but

[1] *Trans Inst of Mining Engineers,* 1912

the mines could be safely worked and illuminated with electricity, and miners' nystagmus prevented, for this is due to the dim light of the safety lamp The problem possibly may be solved by purifying and cooling the return air, and mixing and circulating this with a sufficiency of fresh air

Owing to the fact that the percentage of CO_2 is the usual test of ventilation and that only a very few parts per 10,000 in excess of fresh air are permitted by the English Factory Acts, it is generally supposed that CO_2 is a poison and that any considerable excess has a deleterious effect on the human body No supposition could be further from the truth

The percentage of CO_2 in the worst ventilated room does not rise above 0 5 per cent , or at the outside 1 per cent It is impossible that any excess of CO_2 should enter into our bodies when we breathe such air, for whatever the percentage of CO_2 in the atmosphere may be, that in the pulmonary air is kept constant at about 5 to 6 per cent of an atmosphere—by the action of the respiratory centre It is the concentration of CO_2 which rules the respiratory centre, and to such purpose as to keep the concentration both in the lungs and in the blood uniform (Haldane), the only result from breathing air containing 0 5 to 1 per cent of CO_2 is an inappreciable increase in the ventilation of the lungs The very same thing happens when we take gentle exercise and produce more CO_2 in our bodies

At each breath we rebreathe into our lungs the air in the nose and large air-tubes (the dead-space air), and about one-third of the air which is breathed in by a man at rest in dead-space air Thus, no man breathes in pure outside air into his lungs When a child goes to sleep with its head partly buried under the bed-clothes, and in a cradle confined by curtains, he rebreathes the expired air to a still greater extent, and so with all animals that snuggle together for warmth's sake Not only the new-born babe sleeping against its mother's breast, but pigs in a sty, young rabbits, rats, and mice clustered together in their nests, young chicks under the brooding hen, all alike breathe a far higher percentage than that allowed by the Factory Acts

To rebreathe one's own breath is a natural and inevitable performance, and to breathe some of the air exhaled by another is the common lot of men who, like animals, have to crowd together and husband their heat in fighting the inclemency of the weather

In the Albion Brewery we analysed on three different days the air of the room where the CO_2 generated in the vats is compressed and bottled as liquid carbonic acid. We found from 0 14 to 0 93 per cent of CO_2 in the atmosphere of that room The men who were filling the cylinders and turning the taps on and off to allow escape of air must often breathe more than this The men engaged in this occupation worked twelve-hour shifts, having their meals in the room Some had followed the same employment for eighteen years, and without detriment to their health It is only when the higher concentrations of CO_2 are breathed, such as 3 to 4 per cent of an atmosphere, that the respiration is increased, so that it is noticeable to the resting individual; but percentages over 1 per cent diminish the power to do muscular work, for the excess of CO_2 produced by the work adds its effect to that of the excess in the air, and the difficulty of co-ordinating the breathing to the work in hand is increased

Haldane and Priestley found that with a pressure of 2 per cent of an atmosphere of CO_2 in the inspired air the pulmonary ventilation of a man at rest was increased 50 per cent , with 3 per cent about 100 per cent , with 4 per cent about 200 per cent , with 5 per cent about 300 per cent , and with 6 per cent about 500 per cent With the last, panting is severe, while with 3 per cent it is unnoticed until muscular work is done, when the panting is increased 100 per cent more than usual With more than 6 per cent the distress is very great, and headache, flushing, and sweating occur

Divers who work in diving dress and men who work in compressed air caissons constantly do heavy and continuous labour in concentrations of CO_2 higher than 1 per cent of an atmosphere, and so long as the CO_2 is kept below 2 to 3 per cent. they are capable of carrying out efficient work In the case of workers in compressed air it is important to bear in mind that the effect of the CO_2 on the breathing depends on the partial pressure and not on the percentage of this gas in the air breathed.

By a series of observations made on rats confined in cages fitted with small, ill-ventilated sleeping-chambers, we have found that the temperature and humidity of the air—not the percentage of carbon dioxide or oxygen—determines whether the animals stay inside the sleeping-room or come outside When the air is cold, they like to stay inside, even when the carbon dioxide rises to 4 to 5 per cent. of an atmosphere When the sleeping-chamber is made too hot and moist they come outside

The sanitarian says it is necessary to keep the CO_2 below 0 01 per cent, so that the organic poisons may not collect to a harmful extent The evil smell of crowded rooms is accepted as unequivocal evidence of the existence of such He pays much attention to this and little or none to the heat and moisture of the air The smell arises from the secretions of the skin, soiled clothes, &c The smell is only sensed by and excites disgust in one who comes to it from the outside air He who is inside and helps to make the 'fugg' is both wholly unaware of, and unaffected by it Flugge points out, with justice, that while we naturally avoid any smell that excites disgust and puts us off our appetite, yet the offensive quality of the smell does not prove its poisonous nature For the smell of the trade or food of one man may be horrible and loathsome to another not used to such

The sight of a slaughterer and the smell of dead meat may be loathly to the sensitive poet, but the slaughterer is none the less healthy The clang and jar of an engineer's workshop may be unendurable to a highly strung artist or author, but the artificers miss the stoppage of the noisy clatter The stench of glue-works, fried-fish shops, soap and bone-manure works, middens, sewers, become as nothing to those engaged in such, and the lives of the workers are in no wise shortened by the stench they endure The nose ceases to respond to the uniformity of the impulse, and the stench clearly does not betoken in any of these cases the existence of a chemical organic poison On descending into a sewer, after the first ten minutes the nose ceases to smell the stench, the air therein is usually found to be far freer from bacteria than the air in a school-room or tenement

If we turn to foodstuffs we recognise that the smell of alcohol and of Stilton or Camembert cheese is horrible to a child, while the smell of putrid fish—the meal of the Siberian native—excites no less disgust in an epicure, who welcomes the cheese Among the hardiest and healthiest of men are the North Sea fishermen, who sleep in the cabins of trawlers reeking with fish and oil, and for the sake of warmth shut themselves up until the lamp may go out from want of oxygen The stench of such surroundings may effectually put the sensitive, untrained brain worker off his appetite, but the robust health of the fisherman proves that this effect is nervous in origin, and not due to a chemical organic poison in the air

Ventilation cannot get rid of the source of a smell, while it may easily distribute the evil smell through a house As Pettenkofer says, if there is a dung-heap in a room, it must be removed It is no good trying to blow away the smell

Flugge and his school bring convincing evidence to show that a stuffy atmosphere is stuffy owing to heat stagnation, and that the smell has nothing to do with the origin of the discomfort felt by those who endure it The inhabitants of reeking hovels in the country do not suffer from chronic ill-health, unless want of nourishment, open-air exercise, or sleep come into play Town workers who take no exercise in the fresh air are pale, anæmic, listless Sheltered by houses they are far less exposed to winds, and live day and night in a warm, confined atmosphere

The widespread belief in the presence of organic poisons in the expired air is mainly based on the statements of Brown Sequard and D'Arsonval, statements wholly unsubstantiated by the most trustworthy workers in Europe and America These statements have done very great mischief to the cause of hygiene, for they led ventilating engineers and the public to seek after chemical purity, and neglect the attainment of adequate coolness and movement of the air It was stated that the condensation water obtained from expired air is poisonous when injected into animals The evidence on which this statement is based is not only not worthy of credence but is absurd, *e g*, condensation water has been injected into a mouse in a quantity equivalent to injecting five kilogrammes into

a man weighing 60 kilogrammes No proper controls were carried out. It is recognised now that any distilled water contaminated by bacterial products may have a toxic effect Flack and I have for fourteen weeks kept guinea-pigs and rats confined together in a box and poorly ventilated, so that they breathed air containing 0 5 to 1 0 per cent of CO_2 The guinea-pigs proved wholly free from anaphylactic shock on injecting rats' serum Therefore they were not sensitised by breathing the exhaled breath of the rats for many weeks, and we are certain that no foreign protein substance is absorbed in this way It has been proved by others, and by us, that animals so confined do well so long as they are well fed and their cages kept clean, light, cool, and dry It is wholly untrue that they are poisoned by breathing each other's breath The only danger arises from droplet contagion in cases of infective disease

To study the relative effect of the temperature and chemical purity of the atmosphere I constructed a small experimental chamber of wood fitted with large glass observation windows and rendered air-tight

On one side of the chamber were fixed two small electric heaters, and a tin containing water was placed on these in order to saturate the air with water vapour On another side of the chamber was placed a large radiator through which cold water could be circulated when required, so as to cool the chamber In the roof were fixed three electric fans, one big and two small, by means of which the air of the chamber could be stirred The chamber held approximately 3 cm of air In one class of experiments we shut within the chamber seven or eight students for about half an hour, and observed the effect of the confined atmosphere upon them We kept them until the CO_2 reached 3 to 4 per cent, and the oxygen had fallen to 17 to 16 per cent The wet-bulb temperature rose meanwhile to about 80° to 85° F, and the dry bulb a degree or two higher The students went in chatting and laughing, but by-and-by, as the temperature rose, they ceased to talk and their faces became flushed and moist To relieve the monotony of the experiment we have watched them trying to light a cigarette, and, puzzled by their matches going out, borrowing others, only in vain They had not sensed the diminution of oxygen, which fell below 17 per cent Their breathing was deepened by the high percentage of CO_2, but no headache occurred in any of them from the short exposure Their discomfort was relieved to an astonishing extent by putting on the electric fans placed in the roof Whilst the air was kept stirred the students were not affected by the oppressive atmosphere. They begged for the fans to be put on when they were cut off The same old stale air containing 3 to 4 per cent CO_2 and 16 to 17 per cent O_2 was whirled, but the movement of the air gave relief, because the air was 80° to 85° F (wet bulb), while the air enmeshed in their clothes in contact with their skin was 98° to 99° F, wet bulb If we outside breathed through a tube the air in the chamber we felt none of the discomfort which was being experienced by those shut up inside Similarly, if one of those in the chamber breathed through a tube the pure air outside he was not relieved

R A Rowlands and H B Walker carried out a large number of observations in the chamber, each acting as subject in turn

They recorded the effect on the respiratory ventilation and on the pulse rate both when resting and when working. The work consisted in pulling a 20-kilo weight about one metre high by means of a pulley and rope

In some of the experiments the exhaled carbonic acid was absorbed, and in others carbonic acid was put into the chamber The subjects inside could not tell when the gas was introduced, not even if the percentage were suddenly raised by two The introduction of this amount of the gas made no sensible difference to them, but increased their pulmonary ventilation

In every one of the experiments they suffered from the heat, and the putting on of the fans gave great relief, and in particular diminished the pulse rate during and after the working periods The relief became much greater when cold water was circulated through the radiator and the temperature of the chamber lowered 10° F

The subjects wore only a vest, pants, and shoes in most of these experiments When they wore their ordinary clothing the effect on the frequency of the pulse was more marked and the discomfort from heat and moisture much greater.

I have made observations on men dressed in the Fleuss rescue apparatus for

use in mines, and exposed in a chamber to 120° F. dry dulb and 95° F wet bulb. The skin temperature rises to the rectal temperature and the pulse is greatly accelerated—*e.g.*, to 150—and there arises danger of heat stroke The conditions are greatly relieved by interposing on the inspiratory tube of the apparatus a cooler filled with carbonic-acid snow. The cool inspired air lowers the frequency of the heart and makes it possible for the men to do some work at 95° F. wet bulb, and to endure this temperature for two hours

The observations made by Pembrey and Collis on the weaving-mill operatives at Darwen show that the skin of the face may be 4° to 13° F. higher in the mill when the wet bulb is 71° F. than at home when the wet-bulb temperature is about 55° F. The tendency of the warm, humid atmosphere of the mill is to establish a more uniform temperature of the body as a whole (surface and deep temperatures) and to throw a tax upon the power of accommodation as indicated by the rapid pulse and low blood-pressure.

The mill-workers are wet with the steam blown into the sheds, their clothes and bodies are moist, and the long hours of exposure to such uncomfortable conditions are most deleterious to physical vigour and happiness The operatives asked that they might be allowed to work without steam-injectors and with diminished ventilation, so that the mill rooms became saturated with moisture evaporated from the bodies of the operatives The old regulations, while for bidding more than 6 parts in 10,000 CO_2, put no limit to the wet-bulb temperature, and this often became excessive on hot summer days The operatives were quite right. Less ventilation and a lower wet bulb is far better than ample ventilation and a high wet bulb The permissible limit of CO_2 has now been raised to 11 parts in 10,000, and the wet-bulb temperature is to be controlled within reasonable limits.

The efficiency of workers in mills, mines, tunnels, stoke-holes, &c , is vastly increased by the provision of a sufficient draught of cool and relatively dry air, so as to prevent over-taxing of the heat-regulating mechanism Mr F Green informs me that by means of forced draught the stoke-hole of an Orient steamer is rendered the coolest place when the ship is in the tropics

The electric fan has vastly improved the conditions of the worker in the tropics I would suggest that each clerk should have a fan just as much as a lamp on his desk It will pay the employer to supply fans

In the modern battleship men are confined very largely to places artificially lit and ventilated by air driven in by fans through ventilating-shafts The heat and moisture derived from the bodies of the men, from the engines, from cooking-ranges, &c , lead to a high degree of relative moisture, and thus all parts of the ironwork inside are coated with granulated cork to hold the condensed moisture and prevent dripping

The air smells with the manifold smells of oil, cooking, human bodies, &c , and the fresh air driven in by fans through the metal conduits takes up the smell of these, and is spoken of by the officers with disparagement as 'tinned' or 'potted' air This air is heated when required by being made to pass over radiators Many of the officers' cabins and offices for clerks, typewriters, &c , in the centre of a battleship, have no portholes, and are only lit and ventilated by artificial means The steel nature of the structure prevents the diffusion of air which takes place so freely through the brick walls of a house The men in their sleeping quarters are very closely confined, and as the openings of the air-conduits are placed in the roof between the hammocks, the men next to such openings receive a cold draught and are likely to shut the openings. To sleep in a warm moist 'fugg' would not much matter if the men were actively engaged for many hours of the day on deck and there exposed to the open air and the rigours of sea and weather In the modern warship most of the crew work for many hours under deck, and some of the men may scarcely come on deck for weeks or even months Considering the conditions which pertain, it seems to be of the utmost importance that all the men in a battleship should be inspected at short intervals by the medical officers so that cases of tuberculosis may be weeded out in their incipiency. The men of every rating should do deck drill for some part of every day In the Norwegian navy every man, cooks and all, must do gymnastic drill on deck once a day In the case of our navy, with voluntary service, the men should welcome this in their own interest

In a destroyer visited by me twelve men occupied quarters containing about 1,700 cubic feet of air There was a stove with iron pipe for chimney, from which fumes of combustion must leak when in use, and a fan which would not work. When the men are shut down the moisture is such that boots, &c, go mouldy, and the water drips off the structure The cooling effect of the sea-water washing over the steel shell of the boat is beneficial in keeping down the temperature in these confined and ill-ventilated quarters On the manœuvring platform in the engine-room the wet-bulb temperature reaches a very high degree owing to the slight escape of steam round the turbines Commander Domvile was kind enough to send me the wet and dry bulb temperatures taken there on a number of days The wet bulb was found to be never below 80° F, sometimes reached 95° and even 98° F It is impossible for officers to work at these temperatures without straining the heat-regulating mechanism of the body and diminishing their health and working capacity If such wet-bulb temperatures are unavoidable, means should be provided, such as fans, which would alleviate the discomfort and fatigue caused thereby A supply of compressed air fitted with a nozzle might be arranged and used occasionally to douche the body with cool air I have tried this plan and found it very effectual, and can recommend the compressed-air bath as the substitute for a bracing cold wind

The suitability of the clothing is of the greatest importance, not only to the comfort but to the efficiency of man as a working machine, *e g*, power of soldiers to march On a still day the body is confined by the clothes as if by a chamber of stagnant air, for the air is enclosed in the meshes of the clothes and the layer in contact with the skin becomes heated to body temperature and saturated with moisture

The observations of Pembrey show that himself and four soldiers, marching in drill order on a moderately warm day, lost more water and retained more water in their clothes than on another similar day when they worked with no jacket on. The average figures were loss of moisture 1,600, against 1,200 grms, and water retained in clothes 254, against 109 grms With no jacket the pulse was, on the average, increased 28 against 41 in drill order, and rectal temperature 1° against 1°·5 F The taking off of the jacket or throwing open of the jacket and vest very greatly increase the physiological economy of a march It is absurd that on a hot summer day Boy Scouts should march with a coloured scarf knotted round their necks Nothing should be worn for ornament or smartness which increases the difficulty of keeping down the body temperature The power to march and the efficiency of an army depend on prevention of heart stagnation and avoidance of fatigue of the heart

I conclude, then, that all the efforts of the heating and ventilating engineer should be directed towards cooling the air in crowded places and cooling the bodies of the people by setting the air in motion by means of fans In a crowded room the air confined between the bodies and clothes of the people is almost warmed up to body temperature and saturated with moisture, so that cooling of the body by radiation, convection and evaporation becomes reduced to a minimum The strain on the heat-regulating mechanism tells on the heart The pulse is accelerated, the blood is sent in increased volume to the skin, and circulates there in far greater volume, while less goes through the viscera and brain As the surface temperature rises, the cutaneous vessels dilate, the veins become filled, the arteries may become small in volume and the blood-pressure low, the heart is fatigued by the extra work thrown upon it The influence of the heat stagnation is shown by the great acceleration of the pulse when work is done and the slower rate at which the pulse returns to its former rate on resting

The increased percentage of carbonic acid and diminution of oxygen which has been found to exist in badly ventilated churches, schools, theatres, barracks, is such that it can have no effect upon the incidence of respiratory disease and higher death-rate, which statistical evidence has shown to exist among persons living in crowded and unventilated rooms The conditions of temperature, moisture, and windless atmosphere in such places primarily diminishes the heat loss, and secondarily the heat production, *i e*, the activity of the occupants, together with total volume of air breathed, oxygen taken in and food eaten The whole metabolism of the body is thus run at a lower plane, and the nervous system and tone of the body is unstimulated by the monotonous, warm, and motionless air

If hard work has to be done it is done under conditions of strain. The number of pathogenic organisms is increased in such places, and these two conditions run together—diminished immunity and increased mass influence of infecting bacteria.

The volume of blood passing through, and of water vapour evaporated from, the respiratory mucous membrane must have a great influence on the mechanisms which protect this tract from bacterial infection. While too wet an atmosphere lessens evaporation, a hot dry atmosphere dries up the mucous membrane. As the immunising powers depend on the passage of blood plasma into the tissue spaces, it is clear that a proper degree of moisture is important. The temperature, too, must have a great influence on the scavenger activity of the ciliated epithelium and leucocytes in the mucous membrane of the nose.

In the warm moist atmosphere of a crowded place the infection from spray, sneezed, coughed, or spoken out, is enormous. On passing out from such an atmosphere into cold moist air the respiratory mucous membrane of the nose is suddenly chilled, the blood-vessels constricted, and the defensive mechanism of cilia and leucocyte checked. Hence the prevalence of colds in the winter. In the summer the infection is far less. We are far more exposed to moving air, and the sudden transition from a warm to a cold atmosphere does not occur. We believe that infection is largely determined by (1) the mass influence of the infecting agent, (2) the shallow breathing and diminished evaporation from, and flow of tissue lymph through, the respiratory tract, in warm, moist confined air. Colds are not caught by exposure to cold *per se*, as is shown by the experience of Arctic explorers, sailors, shipwrecked passengers, &c.

We have very great inherent powers of withstanding exposure to cold. The bodily mechanisms become trained and set to maintain the body heat by habitual exposure to open-air life. The risk lies in overheating our dwellings and over-clothing our bodies, so that the mechanisms engaged in resisting infection become enfeebled, and no longer able to meet the sudden transition from the warm atmosphere of our rooms to the chill outside air of winter. The dark and gloomy days of winter confine us within doors, and, by reducing our activity and exposure to open air, depress the metabolism; the influence of smoke and fog, gloom of house and streets, cavernous places of business and dark dwellings, intensify the depression. The immunity to a cold after an infection lasts but a short while, and when children return, after the summer holidays, to school and damp chill autumn days, infection runs around. The history of hospital gangrene and its abolition by the aseptic methods of Lister—likewise the history of insect-borne disease—show the great importance of cleanliness in crowded and much occupied rooms. The essentials required of any good system of ventilation are then (1) movement, coolness, proper degree of relative moisture of the air; (2) reduction of the mass influence of pathogenic bacteria. The chemical purity of the air is of very minor importance, and will be adequately insured by attendance to the essentials.

As the prevention of spray (saliva) infection by ventilation is impossible in crowded places, it behoves us to maintain our immunity at a high level. We may seek to diminish the spray output of those infected with colds by teaching them to cough, sneeze, and talk with a handkerchief held in front of the mouth, or to stay at home until the acute stage is past.

In all these matters nurture is of the greatest importance, as well as Nature. A man is born with physical and mental capacities small or great, with inherited characteristics, with more or less immunity to certain diseases, with a tendency to longevity of life or the opposite, but his comfort and happiness in life, the small or full development of his physical and mental capacities, his immunity and his longevity of life, are undoubtedly determined to a vast extent by nurture.

By nurture—using the word in its widest sense to include all the defensive methods of sanitary science—plague, yellow fever, malaria, sleeping-sickness, cholera, hospital gangrene, &c., can be prevented by eliminating the infecting cause; smallpox and typhoid by this means, and also by vaccination; and most of the other ills which flesh is supposed to be heir to can be kept from troubling by approximating to the rules of life which a wild animal has to follow in the matter of a simple, and often spare diet, hard exercise, and exposure to the open air.

There is nothing more fallacious than the supposition commonly held that

over-feeding and over-coddling indoors promotes health. The two together derange the natural functions of the body. He who seeks to save his life will lose it

The body of a new-born babe is a glorious and perfect machine, the heritage of millions of years of evolution

'Not in entire forgetfulness,
And not in utter nakedness,
But trailing clouds of glory do we come

. . . .

Shades of the prison house begin to close
Upon the growing Boy.'

The ill-conditioned body, anæmic complexion and undersized muscles, or the fat and gross habit, the decay of the teeth, the disordered digestion, the nervous irritability and unhappiness are the result of 'Nurture'—not Nature

In institutions children may be disciplined to vigorous health After leaving school they are set adrift to face monotonous work in confined places, amusement in music-halls and cinema shows in place of manly exercise in the open air, injudicious diet, alcohol, and tobacco—everything which the trainer of an athlete would repel

'And custom lie upon him with a weight
Heavy as frost, and deep almost as life'

The following Reports and Papers were then read —

1 *Fourth Interim Report on Anæsthetics* —See Reports, p 285

2 *Report on Calorimetric Observations on Man* —See Reports, p 283

3 *Report on the Effect of Climate upon Health and Disease*
See Reports, p 290

4 *Report on the Dissociation of Oxy-Hæmoglobin at High Altitudes*
See Reports, p 290

5 *Report on the Ductless Glands* —See Reports, p 291

6 *Report on Electromotive Phenomena in Plants*

7 *Report on the Occupation of a Table at the Zoological Station at Naples* —See Reports, p 186

8 *Report on the Effect of Low Temperature on Cold-blooded Animals*
See Reports, p 292

9 *Patrick Blair's Account of the Nerves of the Trunk of the Dundee Elephant* (1706) *By* AUGUSTUS D. WALLER, *M D , F R S.*

Precisely two hundred years ago—on May 29, 1712—a very remarkable citizen of Dundee, Patrick Blair, graduated as a doctor of medicine at the

University and King's College of Aberdeen In the same year (1712) he was admitted as a Fellow of the Royal Society of London

Blair's name is very slightly known, it has been rescued from absolute oblivion by a short memoir written for the Dundee Symposium by Mr Alexander M. Stevenson, and published in the 'Proceedings' of the Botanical Society of Edinburgh in 1907 From his writings it soon becomes apparent to us that Patrick Blair was a student of science of first rank a discoverer and initiator of cardinal importance, both in vegetable and in animal physiology, a botanist and an anatomist of the pioneer type. The best-known of his botanical works, under the title 'Botanick Essays,' was published in 1720 But the work by which his name is to be earmarked in the history of physiology is that of 1710-12, in which he gives a peculiarly accurate account of the nerves of the elephant's trunk

On April 27, 1709, Patrick Blair, surgeon, from his home at Dundee wrote a letter to Dr Hans Sloane, Secretary of the Royal Society, containing 'a full and exact description of all the bones of an elephant which died near Dundee, April 27, 1706' This letter, under the title 'Osteographia Elephantina,' occupies upwards of a hundred pages of the 'Philosophical Transactions' of the Royal Society, vol 27, 1710-1712, and is illustrated by four plates It appeared as a separate publication under the same title in the year 1713

Blair writes 'After this animal had travelled most part of Europe, she came at last to this Kingdom and when they were come within a mile of this Place, the poor Beast, much fatigued and wearied, fell down She died the next morning being Saturday, April 27th, 1706

'I had not much above an Hour to bestow when Night came on, and that amidst a Throng and Rabble in mighty hot weather

'During that time I caused the Head to be cut off and brought to Town

'On Monday I went out again,' &c, &c

The passages in that monograph that are of greatest interest to us as physiologists are those relating to the anatomy and physiology of the fifth and seventh nerves Any competent judge who examines the text and illustrations of the paper will recognise in it a first-rate contribution to exact knowledge, and the quotation I am about to read will, I am sure, be recognised at once by every physiologist as affording the clearest possible evidence and proof of Blair's high quality For it was published in 1712, more than a century before the problem of motor and sensory nerves in general, and of the two great facial nerves in particular, came to a head Physiologists who are familiar with the writings of Charles Bell and of Herbert Mayo in the years 1821 to 1824, when the functions of the fifth and seventh nerves were made to play a part in the great problem of distinct motor and sensory nerve-channels, will recognise in Patrick Blair, of Dundee, the Dr Blair to whom Mayo refers in 1822 as having 'formed the opinion at the beginning of the eighteenth century from his minute examination of the proboscis of an elephant that the infra-orbital nerves are nerves of touch' Mayo's reference is, indeed, little more than an allusion by means of which he indicates his acquaintance with the subject and his rejection of the account of it that had been published by his master, Charles Bell, in the 'Philosophical Transactions' of the previous year As described by Bell in his first paper to the Royal Society, 'On the Nerves,' read July 12, 1821[1], the fifth nerve is the nerve of sensation and voluntary motion to the skin and muscles of the face, and these same muscles are also supplied by the seventh nerve as regards their respiratory action, he accordingly characterises the latter as a super-added or respiratory nerve, and at page 419 applies this view to the case of the elephant's trunk —

'It has been already stated that when a feeler, or antenna, is examined, if it be simply for sensation, one nerve only runs along it It was suggested to him (the author) that if his theory were true the trunk of the elephant, being hollow and connected with respiration, it should have two nerves, whereas in the observations of Cuvier it was stated to have only one An opportunity of ascertaining the truth of this was very liberally granted by Mr. Herbert Mayo, who had lately a young elephant for dissection. The two nerves were readily found, both

[1] *Phil. Trans. R.S.*, part ii., 1821, pp. 398-424.

of great size; the one a continuation of the superior maxillary branch of the fifth, the other the continuation of the respiratory or seventh '

It is perfectly clear from this extract that Bell, of his own knowledge, was not acquainted with the nerves of the elephant's trunk, nor with Blair's description of them The whole of his paper is directed to support his speculation that the facial muscles have a double nerve-supply by an 'original' and by a 'superadded' nerve

It is equally clear that his pupil Mayo had given special attention to the subject, and that he was acquainted with its literature He does not quote Blair's actual words, but mentions what he reads from them as their essential point, and gives a precise bibliographical reference, from which any careful reader—then or now—is enabled to draw his own conclusions

Mayo writes, at the end of his own first publication on the subject at p 119 of his 'Anatomical and Physiological Commentaries' of July 1822 —

'It remains for the reader to decide whether Mr Bell's experiments are satisfactory, and bear out his inferences, whether the latter, coupled with my former observations on the five respiratory nerves of this author, leaves his theory tenable, and perhaps finally to determine whether there exists in the whole of Mr Bell's essay, after the deduction of his controvertible statements, more than one correct inference I here allude to Mr Bell's experimental confirmation of an opinion which, at the beginning of the eighteenth century, occurred to Dr Blair[1] on his minute examination of the proboscis of an elephant, viz that the infra-orbital nerves are nerves of touch

Blair writes[2] of the nerves of the proboscis on p 84 —

'This extraordinary part did not want for Nerves sufficient for it, no more than Blood-vessels For first, it has the *nervus Olfactorius*, whereof hereafter, whereby 'tis endu'd with a most acute Sensation of Smelling 2dly the aforesaid second Branch of the fifth Pair, which accompany the Blood vessels, is with them dispers'd throughout the whole substance of the *Proboscis*, by which it has so acute a sensation of Touching or Feeling, wherewith this Member is more signally endued, and by which it avoids whatever is hurtful to it 3dly the hard portion of the *Nervus Auditorius*, which tho' it be dispers'd in the Muscles of the Face in Human Subjects, yet in Quadrupeds, such as Oxen, it continues undivided, till it comes to the angle of the lips This seems to be chiefly adapted for the different motions of the *Proboscis*, for as we see in the *Musculus Rectus Abdominus*, that at each of the tendinous interstices, whereby its fibres are several times gathered together, a Nerve enters at the beginning of each *Fasciculus*, So here the Muscles of the Proboscis being divided into several *Fasciculi*, each of them have a Branch of this Nerve dispers'd in them, and 'tis situated on each side, that it may the more conveniently disperse its Branches both to the *Fasculi* of the *Elevatores* and *Retractores* alternatively

'Thus you see how signally this Member is endued with Instruments for the Performance of its different Functions 'Tis the principal Seat of the two Senses, and partially partakes of the Third For by it the Animal smell'd, by it Feeling is perform'd, as by the Hands with us, wherefore the *Proboscis* is not improperly call'd *Manus Nasura*, as before we observ'd, and by it the 5th pair of Nerves affords a partial Idea of the Taste, to what Food it takes hold of, before it conveys it to the Mouth, and it has a great Analogy to the other two Senses, viz, to the Eye by its three pair of Nerves, namely, one for its Seeing, analogous to the other for Smelling, one for its pathetical Motions, analogous to the acute Sensation, afforded to the other by the fifth pair, and one for the motion of its other Muscles, analogous to the hard portion of the other, and to

[1] ''Tis observable both in Human Subjects and Quadrupeds, that there is an Hole below the Orbit of the Eye in the *Os Maxillæ Superioris*, through which the Superior Branch of the Second Division of the fifth pair of Nerves passes, surrounding in its Progress a Vein and an Artery, all which are dispersed in the Muscles of the Cheeks, Lips, and Nose, and furnish branches for the Roots of the Teeth of the Upper Jaw This Hole is not so considerable in Human Subjects, but larger in Quadrupeds, especially such as feed upon Grass and Hay '

[2] *Phil Trans R S*, vol 27, 1710 1712, No 326, p 51, No. 327, p. 117.

the Tongue[1] as we have already shew'd at large, by its different Motions, and by its partial Taste'

Surely no student of physiology accustomed to search the sources of his knowledge in the words spoken or written by the great students of Nature who have themselves first raised some corner of the veil, can fail to recognise that Patrick Blair was a great student, and that his intelligence in 1710 of the functional attributes of the fifth and seventh nerves was far superior to that of Charles Bell in 1821, and of Herbert Mayo in 1822, and was surpassed in precision only by the illuminating discovery of Magendie in 1822 upon the nerve roots, whereby order was imposed upon our elementary conceptions of the nervous system, and the fifth and seventh nerves assigned to their proper place in that order

10 *The Electrocardiogram by the Oscillograph.* *By* Augustus D Waller, *M D*, *F R S*

11 *On Blood Coagulation* *By* Drs W Cramer *and* H Pringle

12 *On the Biochemistry of Growth* *By* Dr W Cramer

13 *The Physiological Action of Quaternary Methyl-, Ethyl-, and Methyl-Ethyl-Ammonium Compounds* *By* C R Marshall

These tetra-alkyl-ammonium compounds present some features of interest from a physiological point of view. Like most quaternary compounds they exert, in frogs, a depressant action on the myoneural junction of voluntary muscle, and in sufficient doses cause complete muscular paralysis The tetra-methyl-ammonium compounds are most powerful in this respect, and the tetra-ethyl compounds are weakest The dose, injected into the dorsal lymph sac, necessary to abolish spontaneous muscular movements and loss of hind-limb reflexes in frogs of approximately 10 grammes in weight was found to be for

	Mg per Gramme Body-weight
Tetra-methyl ammonium chloride	0 02
Trimethyl-ethyl-ammonium chloride	0 025
Dimethyl-diethyl-ammonium chloride .	0 25
Methyl-triethyl ammonium chloride	1 0
Tetra-ethyl-ammonium chloride	2 5

Contraction of the pupils and weakening or paralysis of the pulmonary respiration are the earliest symptoms In the case of tetra-ethyl ammonium chloride fibrillary contractions of all the muscles quickly develop and form the most marked feature of the intoxication They occur in frogs in which the brain and spinal cord have been destroyed, and they can be prevented or abolished by tetra-methyl-ammonium chloride In frogs to which methyl-triethyl-ammonium chloride has been given somewhat similar contractions can be developed for a short time by shaking the table, and they occur when the animal is laid down These fibrillary contractions were not seen after the administration of any other members of the series The heart and muscles are affected by these substances, but to a less extent—except, perhaps, in the case of tetra-ethyl-ammonium chloride—than the motor-nerve endings

In mammals the only effect of these substances I have studied with care is that upon the respiration When 1 to 2 mg tetra-methyl-ammonium chloride is injected intravenously into anæsthetised rabbits or cats the respiration ceases

[1] 'I think I may with good Reason make an analogy between it (the Proboscis) and the Tongue . For besides there is a great Affinity betwixt the Smelling and Tasting, since what's unpleasing to the Nose, cannot but nauseate the Tongue and Palate; inasmuch that the Nose may be call'd a Taster to the Taste.'

a few seconds afterwards and recommences a few seconds later, and gradually attains its previous form The effect is obtained with larger doses of other members of the series With tetra-ethyl-ammonium chloride very large doses (20 to 40 mg) are required, and even these are not always effective Instead gradual failure of the respiration may occur This temporary paralysis of the respiration was ascribed by Tappeiner and Iodlbauer to stimulation of the fifth cranial nerve in the nose, and was said not to occur after cocainisation of the nasal mucous membrane This I have been unable to corroborate The effect is not obtained by injection of strong concentrations of tetra-methyl-ammonium chloride into the nasal cavity, and it is obtained in a modified form after division of both fifth nerves in the base of the skull Moreover, the effect runs parallel to the diminution or loss of irritability of the diaphragm and fore-limb muscles to electrical stimulation of their nerves, and the doses of the various members of this series required to produce it are of the same order as those required to produce motor paralysis in the frog It would seem therefore that the effect is partly, if not wholly, due to depression of the motor-nerve endings in the respiratory muscles

---

14 *The Pharmacological Action of Nitric Esters* By C R MARSHALL

Pharmacologically the nitric esters act mainly on unstriped muscle-fibre and especially on that of the arterioles Their chief effect is to cause a fall of blood-pressure owing to dilatation of the blood-vessels That the action is peripheral may be shown by perfusion of the vessels of an isolated organ and in other ways Doses producing distinct vaso-dilatation have no appreciable direct action on other organs of the body, but in men their administration is frequently followed by severe headache The cause of this is unknown, but as it is not proportional to the degree of vaso-dilatation, it cannot, I think, be wholly ascribed to this action

Large doses cause metheamoglobinæmia, and if the dose be sufficiently large, death, in mammals, results from this cause

The nitric esters I have so far prepared and investigated are —

Methyl nitrate
Ethyl nitrate
n-Propyl nitrate
iso Propyl nitrate
n-Butyl nitrate

Glycol dinitrate

Glycerol trinitrate
Glycerol dinitrate
Methyl glycerol dinitrate
-Dichlorhydrin nitrate

Erythritol tetranitrate
Pentaerythritol tetranitrate

Arabitol pentanitrate
Mannitol hexanitrate
Mannitol pentanitrate
Dimethyl mannitol tetranitrate
Tetramethyl-mannitol dinitrate

Dulcitol hexanitrate
Dulcitol pentanitrate
Sorbitol hexanitrate

Arabinose tetranitrate
Glucose pentanitrate
Fructose pentanitrate
Rhamnose pentanitrate
Quercite pentanitrate
Saccharose octonitrate

Tartaric acid dinitrate
Ethyl-tartaric acid dinitrate
Citric acid nitrate
Ethyl citric acid nitrate
Lactic acid nitrate
Ethyl-lactic acid nitrate

Cellulose nitrates
Starch nitrate

For the present purpose these substances may be divided into four groups

(i) The nitric esters of the monhydric alcohols
(ii) The nitric esters of the polyhydric alcohols and sugars.
(iii) The nitric esters of starch and cellulose
(iv) The nitric esters of the acids and their alkyl compounds

The members of the last two groups do not produce the characteristic vaso-dilatation of most nitric esters—the nitric esters of starch and cellulose owing

to their insolubility in aqueous media, the nitric esters of the acids owing apparently to what we may term the inhibiting influence of the carboxyl group In the case of some of the ethyl esters of the last-named compounds a fall of blood-pressure commences some minutes after an intravenous injection, the cause of which has not yet been ascertained

The first group—the nitric esters of monhydric alcohols—are relatively weak vaso-dilators Methyl nitrate, for example, injected intravenously, is more than ten times weaker than glycerol trinitrate, and when administered by the stomach to man, is more than a hundred times weaker They can be given in sufficiently large doses to rabbits to produce unconsciousness without causing death

The vaso-dilating action of the remaining group—the nitric esters of the polyhydric alcohols and sugars—considering their solubility, is powerful The differences exhibited by the various substances are mainly quantitative and are largely due to the differences in solubility of the substances in aqueous media The presence of hydroxyl groups, however, diminishes the action of a substance as compared with the fully nitrated compound very considerably

The action of the nitric esters seems to be associated with their susceptibility to reduction and conversion into nitrites under the influence of caustic alkalies, and it is not improbable that a similar reduction occurs in the muscle-cells themselves.

15 *On Coriamyrtin and Tutin* By C R Marshall

Coriamyrtin is the active glucosidal principle in *Coriaria myrtifolia* (L), an ornamental shrub indigenous to many countries bordering the Mediterranean Tutin is a similar principle, present in the New Zealand species of *Coriaria*—viz , *C ruscifolia* (L), *C thymifolia* (Humb and Bonp), and *C angustissima* (Hook) Both are colourless crystalline substances, but they differ in chemical composition and in physical characters

Both substances produce similar pharmacological effects, but coriamyrtin is more powerful, more rapid, and more transient in its action than tutin When injected subcutaneously into rabbits they produce a marked increase in the frequency of the respirations and a slowing of the pulse-rate, often salivation, followed, if the dose is sufficiently large, by convulsions After large doses the earlier convulsions are partly tetanic in character, the later ones are usually wholly clonic After small convulsive doses the whole of the convulsions are generally clonic in character They commence in the head, and extend, if they do extend, posteriorly The Jacksonian character of these convulsions is better seen after tutin than after coriamyrtin Both substances produce a fairly constant type of 'forced movements' They occur most typically as end reactions after large convulsive but non-toxic doses of tutin A fall of body temperature is produced both by convulsive and non-convulsive doses of the two substances

The respiratory and cardiac effects are due to stimulation of the medullary centres There is also stimulation of the vasomotor centre The convulsions are due to increased excitability of all parts of the central nervous system The cortical motor-centres are most susceptible, but clonic convulsions are obtained after excision of the cerebral hemispheres, and tonic-clonic movements may be obtained in the hind limbs of cats after the division of the spinal cord in the lower dorsal region This increased excitability of the spinal cord is more easily obtained with coriamyrtin than with tutin

Anæsthetics, and especially chloroform, greatly diminish and may annul the stimulant action of these substances on the medullary centres The respiratory centre seems most susceptible to this change Instead of a large increase in the frequency of the respirations there is, with full anæsthesia, a diminution, with deeper and more prolonged inspiration This effect appears relatively late and is usually accompanied or quickly followed by slight twitches of the limbs It is, therefore, probably to be ascribed to an increase in tone of the respiratory muscles rather than to a specific action on the respiratory centre

In frogs these substances produce increase in the frequency of the respiration, the appearance of muscular stiffness, with sluggishness of movement and incoordination, so that the animal assumes bizarre positions and sinks on the table, and later convulsions, mainly tonic in form The main difference between the

two glucosides is quantitative, coriamyrtin acts more rapidly and more powerfully than tutin. Thus, while 0 033 mg per gramme body-weight of coriamyrtin induced convulsions in three minutes, the same dose of tutin took thirty-eight minutes The minimum convulsive dose for frogs is, for coriamyrtin 0 0012 mg per gramme, for tutin 0 012 mg per gramme body-weight

16 *Surface Tension as a Factor in determining the Distribution of Salts in Living Matter* By Professor A B MACALLUM, *F R S*

---

17 *The Secretion of a Mineral Acid by the Kidneys* By W R CAMPBELL *and* Professor A B MACALLUM, *F R S*

---

18 *Biological Economy* By H REINHEIMER

Political and biological economy are complemental The more this is realised the more it becomes evident that the Malthusian generalisation employed in Darwinism is devoid of biological sanction Constitutionally, organisms are constrained to perform labour, which is activity systematically applied It is normal for organisms to produce values and to render services The economic bond in which they are involved implies due limitation and restraint as regards feeding and reproduction

The common interests involve praise or blame of each individual or group in the degree that their economic behaviour aids or hinders those interests The self-preservation of the organic world demands sympathetic economic relations, whatever is helpful in this direction is legitimate, whatever impedes is illegitimate

The production of wealth demands a thing to be wrought and individuals to use it Sun and earth are the sources of all organic productions, in which productions under the existing division of labour all classes of organisms co-operate Hence wealth production is not confined to man The lowest and humblest organisms are often very real economic individuals

The fundamental principles of trade—give and take—have been complied with as the rule of progressive life before man's advent Symbiosis, cross fertilisation, cultivation, and distribution of seeds are typical examples Reproductive as well as productive powers are subservient to the general interest

Cross-fertilisation, based on wholesome economic activity, with generally wholesome results, is superior to self-fertilisation, which is more liable to abuse The position of plants in the evolutionary scale is according to production of valuable substances

The large facts of Nature proclaim that economic sterility spells degeneration Compare the economist's teaching that labour is the only source of wealth

Degeneration is not synonymous with simplification or progressive atrophy

The term 'useful' in biology is confounding without a definite standard The 'usefulness' of degeneration is fictitious

The 'in-feeding' habit causing metabolic abnormality, detrimental to mutual aid, is the usual associate of degeneration It is chiefly responsible for determining inferior environments Cross feeding, analogous to cross-breeding, is superior to 'in feeding' Parasitism originates in 'in-feeding' habits The intensification of the ensuing metabolic abnormality—parasitic diathesis—causes antithetic and teratological developments—sexual dimorphism female preponderance in parthenogenesis and those phenomena of increase of size during palæontological periods which Cope's law takes into account

The view that parasitism is but a peculiar physiological habit is insufficient It over emphasises attachment whilst under-estimating food-stimulation and the resulting pathology, being prejudiced against the obvious pathological conclusion by the corollary of the doctrine of Natural Selection, which asserts that whatever is, is best.

The prodigious reproduction of parasites suggests processes of intracellular

dissociation The startling limitations of the parasitic life, its uneconomic nature, its astounding liability to infection, to pædogenesis, and reproductive nemesis mark it as a life of failure

One inference is that the retention of vital intra- and extra organismal correlations depends upon maintenance of economic integrity least calculated to distort the intra- and extra-organismal metabolic balance

---

FRIDAY, SEPTEMBER 6

The following Papers were read —

1 *The Physiological Basis of Memory and Abstraction* By MAX VERWORN

Upon the basis of the neurone theory the problem which arises for physiological psychology is the ascertainment of the physiological conditions of the sensory processes in the neurones Here one of the first problems is the question concerning the fundamental principle involved in *memory* what are the traces remaining after excitation, produced by the sensory processes in the neurones, concerned? It has been assumed that they consist in molecular alterations resulting from the process of excitation The maintenance of that view meets, however, with some difficulties The molecular alterations brought about in the neurones by the stimulus during excitation consist, as has previously been shown, in a disturbance of the metabolic equilibrium by an increase of the processes of oxydative disintegration Immediately following each excitation, however, metabolic equilibrium is again restored, and every trace of the excitation process appears obliterated Still, even though the process produces no molecular alteration, a secondary result remains, which consists in an increase of the mass of the living cell This only becomes clearly manifest when the excitation is of frequent recurrence, and is then expressed by functional hypertrophy The presence of the latter can be demonstrated in the neurones as well as in every other living substance It forms the cellular basis of memory by increasing the intensity of the discharge of impulses, and with this the specific action of the neurone This recurring use leads to a facilitation of the tracts (Ausschleifen der Bahnen), and thus to a greater intensity of the specific action of neurone chains resulting from the repeated demands We find this demonstrated in the association processes of the cerebral cortex by the predominance of the facilitated conceptions, in response to a stimulus over others not practised in this manner In lapse of memory resulting from want of practice, the reverse process takes place Here the unused neurones fall into an atrophy by inactivity

These facts afford us insight into the process of *abstraction* All our conceptions are complex in their nature The abstract conceptions are distinguished from the concrete by the fact that the former, in the specific manner of the adjustment of their components, have no correlation in the sensory world, whereas the latter are fully in accordance with those things which can be perceived through the senses In spite of this, however, the material from which the abstract conceptions are built up is likewise individually derived from sensory perception, and even the most abstract conceptions are composed of sensory elements In the genesis of abstract conceptions the principle is merely that in a number of association complexes gained by sensory perception, having in part common, in part different components, the common components which return with greater frequency are developed by use, whereas the special components, which recur seldom, or not at all, fall into atrophy and recede into the background As the neurone stations, which correspond to the common components, undergo, by more frequent functional demands, a hypertrophy, they consequently predominate later in response to a stimulus by the intensity of their discharge, that is, of their specific function Thus, finally a framework of associated conceptions is formed, in which only the most frequently recurring components of a complex are left over, whilst the other, through atrophy by inactivity, have disappeared more and

more Here is to be found the reason that abstract conception in regard to their specific structure finally possesses no precise correlation in the world of sensory perception

2 *Discussion on the Relation of Mind to Body*

(i) *From the Standpoint of Philosophy* By R Latta, M A, D Phil

It is almost impossible to treat this problem from a purely scientific point of view without introducing metaphysical considerations This is due to the fact that at the present stage of our knowledge the problem is to a great extent a problem of method There are two main groups of theories, the parallelist and the animist, the latter including various forms of the interaction theory The parallelist theory was first set forth by the Cartesian philosophers, and there has been no essential development of the position since the time of Spinoza It rests on the mechanical hypothesis of physical science, according to which all physical phenomena may be regarded as forming a self complete and self-explaining system This system excludes nothing except what is non-material Parallelism consists essentially in the hypothesis of a similar mechanical system of mental phenomena, corresponding point for point with the physical system, but entirely independent of it We have thus in parallelism an *a priori* extension of the mechanical hypothesis to mind, although the basis of the mechanical hypothesis was the necessity of excluding everything mental from the physical system Parallelism, accordingly, transforms the mechanical method from a scientific hypothesis into an ultimate metaphysical principle On the other hand, the vitalist and animist theories insist on the recognition of a teleological factor in organism and in mind They are thus in direct opposition to the mechanical hypothesis, as it was originally conceived, for this hypothesis had as its aim the rejection of final causes as principles of explanation in the physical world The mechanical view is right in rejecting final causes if they are regarded not as immanent in nature, but as external and accidental The vitalist and the animist are right in insisting on a teleological factor, but they expose themselves to criticism from the mechanist point of view by placing the teleological factor entirely outside the mechanical system The two realms, the mechanical and the teleological, thus remain, on the animist view, as much apart as they are on the mechanical theory But teleology is not external, but immanent Wherever we have system, we have final cause, and the ends are not outside of the system If the physical world is a real system, it has an immanent teleology If the mental is also teleological, we may set aside the hypothesis of a gulf between the two realms, and recognise that the distinction of the physical from the psychical is a distinction within one system This brings us nearer to the actual facts of experience, and it does not mean the merging of one system in the other or of both in a vague unity, for increasing knowledge means more exact and real distinction, and at the same time the recognition of more profound unity between the things distinguished

(ii) *From the Standpoint of Psychiatry*
By Sir Thomas Clouston, *M D, LL D*

Psychiatry is a word of German origin expressing the study and treatment of mental diseases and defects Psychiatry implies the general assumption that body and mind have a constant and necessary relationship The progress of physiological science and of modern psychology has compelled the psychiatrist to the conclusion that the brain is the necessary vehicle of mind, and therefore the study of brain in its physiological and pathological relations is by far the most important, indeed the absolutely necessary, preliminary to his work

It is definitely proved that when the brain is not developed in a normal way from birth onwards the mental functions are also non-developed Careful observation has also shown that under these conditions the outward expressions of mind, in the shape of speech and the workings of the mind-muscles of expression in the face and eye, are usually accompanied by what have been wrongly

termed the 'stigmata of degeneration,' which are really the stigmata of non-development

It is now almost demonstrated that all the serious forms of mental disease can be associated directly with microscopic and bio-chemical alterations in the brain-cells We find that in the brain there is a general solidarity of action, which in a way may be said to correspond to the metaphysical doctrine of the unity of mind, but that doctrine has to be extended so as also to include the unity of mind and body If the term 'unity' goes too far, the term 'parallelism' is certainly a correct description of the facts

A bad nervous or mental heredity tends especially to interfere with the development process of body and mind If that heredity is very strong, we are apt to find complete arrestment as in idiocy, where it is less strong, we have attacks of mania and a tendency to that mental arrestment and death which I have called 'adolescent insanity,' and subsequently 'dementia' or mindlessness The normal power of the brain and mind to react to stimuli is impaired in some way in all cases of mental disease This abnormality necessarily upsets the social life of the community

The highest quality required for human society is the power of mental inhibition or self-control We cannot dissociate that from bodily inhibition We conclude that there are centres of mental inhibition, probably situated in the fore part of the brain, which are non developed in idiocy, poorly developed in the primitive races, and diseased in the insane This is one of the most important relationships of body and mind, and is one of the most essential parts of psychiatric study

I think the facts which are often described by the term 'subconscious' and 'subliminal consciousness' are much better understood and fall in with physiological facts by being looked on as merely molecular and bio chemical changes within the brain-cells

(iii) *From the Standpoint of Physiology*
By J S HALDANE, *M D , F R S*

From the everyday point of view a man or higher animal is a personality consciously and purposively controlling, with greater or less success, his body, and through it the surrounding environment From another point of view, however, the behaviour of the man is dependent on his physical environment, and on the blind physical or physiological processes occurring around and within his body His perceptions and actions, and his continued existence, depend absolutely on the material and energy coming to him from the environment, and on the bodily structure transmitted to him from his parents From this point of view no independent mind or soul can be distinguished, all psychical activity is demonstrably dependent on the body and its physical environment, and is apparently a mere accompaniment of physiological changes The facts on which this conclusion depends appear at first sight to be unassailable, and to become more and more cogent with every year of advance in knowledge

These two views clash with each other If we adopt the first view, we are faced by the hard facts on which the second view depends If we adopt the second, we encounter the difficulty that, from their very nature, physical and mere physiological processes afford no explanation of intelligent behaviour The difficulties of the first view have been sufficiently emphasised in recent times in consequence of the great advances in physical and physiological knowledge But the difficulties of the second view are equally great, if not greater They have been admirably stated in Dr McDougall's recent book on 'Body and Mind,' to which I may refer

These difficulties cannot be solved by any theory of interaction between the body and the mind or soul Between body and mind there is no interaction, simply because the body, more fully understood, *is* the mind From the physical and chemical standpoint a man is about 70 kilogrammes of material with a certain configuration, properties, and internal movements this material consisting of a great variety of chemical compounds, interacting upon one another in various ways From the physiological standpoint the man is a living organism blindly fulfilling its biological destiny From the psychological stand-

point he is a person, the subject of purposive knowledge and volition The man as mere physical body or organism is an evident fiction or abstraction from reality, though a very necessary one for our imperfect knowledge As a conscious individual personality he is at least far less of a fiction But we can often get no further than a physical or physiological account of reality, and for this reason the physical or physiological account of man can never be dispensed with

The physical sciences, biology, and psychology, go on their several ways, accumulating knowledge which each science interprets according to its own working hypothesis and subject to the limitations due to the abstractions from reality which are involved in these hypotheses Each lower science also hands on what is, relatively speaking, raw material to the higher one The attempt to resolve the higher into the lower, as by making mind dependent on body, is foredoomed to failure The corresponding attempt to resolve the lower into the higher, as by making body dependent on mind, is also impossible, for the knowledge which would justify such an attempt is lacking, even were such knowledge conceivable

It seems to me that it is only by this general conception of the relation of physical and physiological to psychological knowledge that each science can gain for itself a clear field of operation, and escape from the confusion which results from wrongly applying scientific hypotheses to what lies outside their scope In practical life we draw no such distinctions, for we use every scrap of knowledge we possess however partial or mutually contradictory these scraps may be We live and move in a world of apparent contradictions, within which science, religion, and philosophy afford us only a general guidance In this practical life the question of the relation of body to mind comes up in a piecemeal form, and can only be answered in a similar fashion, as it is answered every day in practical medicine, where we sometimes regard the body as dominating the mind, and sometimes the mind as dominating the body Such answers are, however, not those of science or philosophy We cannot generalise from them, and the attempt to do so leads only to confusion

(iv) *From the Standpoint of Psychology* By H J Watt, *Ph D*

The scientific problems concerning the connection between body and mind grow out of the interdependence of the two, which we all learn to recognise, not merely by reflection but also by virtue of the diverse behaviour of experiences essentially identical or parallel, *e g* sensations and images In the physical sciences uniform and more or less consistent schemes of arrangement and interconnection of elements and other units have been adopted But no general hypothesis of psychical structure has yet been established Any considerable advance in the study of the relations of body and mind must therefore be made from the side of psychological science

The connection between body and mind must rest upon some form of correlation between the realms of 'material' and 'psychical' things, in so far as it is agreed that some or all psychical processes are accompanied by or are evoked by, physical processes or *vice versa* The scope of this correlation cannot well be explored from the physical side, as obviously not all physical processes and all aspects thereof have a discoverable psychical counterpart The task for psychology is, then to form an exhaustive list of psychical states, whether elements, compounds, or other derivatives, and to ask for each of these and each distinguishable aspect thereof whether some satisfactory correlative cannot be found among known or possible physical processes and their predicable aspects Such a psychological analysis has been involved in every theory of the relation between body and mind An attempt to reduce the scope of correlation by a proof that the unitary nature of psychical processes has no physical counterpart will be considered Allowing for mind not only the rule of the identity of indiscernibles, but also the integration of limited differences within partial identity according to specific rules to be discovered we need not invoke the soul or any other psychical agent in order to explain these rules, any more than in physical science we need assume the presence of 'forces' to explain physical laws

3 *Blocking Nerve Impulses aroused in Cut and Intact Nerves, and in Strychninised and Normal Frogs* By CHARLES M GRUBER

The object of the investigation, of which a brief sketch follows, was to study the practical value of the tripolar block upon impulses aroused by different kinds of stimuli, and to compare its efficiency and advantages with the nerve blocks produced by other methods upon cut and intact nerves in the frog

From many investigations it has been demonstrated that nerve conduction may be inhibited by the same forces, but of different degrees, as those that arouse nerve impulses and effect stimulation—namely, mechanical (compression), chemical (cocaine and magnesium sulphate), thermal (freezing), and electrical (either faradic or galvanic bipolar or tripolar currents)

The tripolar galvanic current is usually used for stimulation, though it has in a few instances been employed to block vagus impulses In this investigation the tripolar current was brought to the nerve by interpolating between the non-polarisable electrodes and the nerve zephyr fibres moistened in normal salt solutions

It was proved from the first that the bipolar method was less efficient than the tripolar, and it was therefore abandoned

The stimulating current consisted of the minimal faradic strength that caused a maximal contraction of the gastrocnemius muscle Such contractions instantly ceased when the block circuit was closed, and reappeared immediately when it was broken

The strength of the current necessary to block the impulses varied from eight to twenty-five volts, depending upon the kind of stimuli and also upon the condition of the frog The strongest tetanic contractions produced by stimulating the sciatic nerve with the faradic current in frogs in good condition required, as a rule, about twenty volts in the block circuit

Strychnine tetanus was inhibited with weaker currents, as were also efferent impulses reflexly produced by stimulating either the foot or nerve of the opposite leg

Any of the legs can be severed without causing reflex contractions in the leg to which the block-current was sent, or by placing the tripolar block on its innervating nerve above the cut

The tripolar block can be applied repeatedly both to cut and intact nerves, but with slight, if any, after effects upon the functions of the nerve

Afferent impulses were inhibited by currents of only one tenth of the strength necessary for efferent fibres

In every case the efficiency of the block was proved also by the absence of action currents beyond the block

The advantages of the tripolar block, as compared with the others that were investigated, are readily seen when we consider that it requires about an hour before magnesium sulphate or cocaine produce an efficient block, and they have an injurious after-effect upon the function of the nerve However, they act alike on both cut and intact nerves, and that the freezing mixtures, especially liquid air, require several minutes before they produce blocking, and many more before their effect passes off, although the freezing may be applied repeatedly without injurious after-effect upon intact nerves

But it is interesting to note that freezing the nerves, either before or after cutting them, destroys their function at the blocked area This fact is one of the conspicuous differences between the different blocks experimented with

The tripolar galvanic block current therefore proved superior to the others in several respects It may be employed indefinitely on both cut and intact nerves, acts instantaneously, and its effect is just as quickly removed without injury to the function of the nerves, and what is also of importance is, that we have in it an effective, ready power, by means of which we can exclude the conductivity of the afferent fibres in the mixed nerve trunk

It is possible that it may prove a practical and valuable aid in surgery and for experimental purposes.

4 *A Comparison of Naturally and Artificially aroused Impulses under the Influence of Nerve Blocks* By CHARLES M GRUBER.

The research, of which a brief report is here presented, was begun by Dr Hyde several years ago, at the suggestion of Dr C S Sherrington, in his laboratory in the University of Liverpool, and was completed by one of Dr Hyde's research students

It was conclusively proved by me that impulses aroused by artificial stimuli in a frog's sciatic nerve can be suppressed by the tripolar electrical block, liquid air, and other blocking agencies, and that the tripolar block could be repeatedly introduced in the circuit without injury to the nerve's function Also that afferent impulses could be inhibited with weaker currents than could the efferent impulses It was of interest, therefore, to ascertain whether natural impulses originated by higher centres in the brain were physically of the same nature as those electrically produced, and could be suppressed by the same kind and strength of block as could those artificially aroused by the electrical current

The experiments were conducted on the phrenic nerves in rabbits By means of a modification of Head's method, records of the movements of the diaphragm and the thoracic wall were obtained The artificial stimuli were the threshold strengths of the faradic currents applied to the phrenic nerve and its branches, the movements of the diaphragm in response to these stimuli and the contractions of the diaphragm resulting from the stimuli emanating from higher centres in the brain were recorded and compared If the phrenic nerve or any of its branches are stimulated with the weakest possible current, it is responded to, throughout the period, by a contraction of the diaphragm or an inspiratory phase of the side stimulated The efficiency of the tripolar electrical block was compared with others, especially those produced by cocaine and freezing mixtures, and liquid air

It was found that the contractions of the diaphragm were suppressed the instant, and throughout the period, that the tripolar block circuit was closed The strength of the block current was not more than $(2\ 8)^2$ volts, and this strength would suppress the cranial or naturally aroused impulses, as well as those originated by the very weakest faradic current Only in one experiment did a block of $(1\ 4)^2$ volts inhibit the cranial, but not the artificially aroused, impulses

But cocaine, a freezing mixture of sodium chloride and ice, or liquid air, proved efficient in suppressing the impulses originated by the higher centres in the phrenic as well as those produced by electrical stimuli But these blocks are inferior to the tripolar, because they cannot be repeatedly employed without injury to the function of the nerve

The presence of afferent fibres in the phrenic was well demonstrated by a simple experiment When the motor impulses on one side were blocked, and the phrenic stimulated centrally to the block, a change in rate and amplitude of the diaphragmatic movements of the opposite side followed, as was indicated by the contraction curves secured from the diaphragm slips on that side The same result was obtained when the phrenic of one side was cut and the central cut end stimulated Stimulating or irritating the peritoneum in different regions of the abdomen with intact phrenic is followed by a change in rate and force of the respiratory movements This is, however, probably due to afferent stimuli from nerves other than the phrenic to the respiratory centre

---

5 *The Influence of Alcohol upon the Reflex Action of some Cutaneous Sense Organs in the Frog* By Professor IDA HYDE, MISS R SPRAY, *and* MISS I HOWAT

A search of physiological literature reveals the fact that very little work has been done in regard to certain questions which form the basis of a research, a summary of the results of which I should like to present—namely, how soon after administering a minimal and also stronger doses of alcohol does a change in reflex time appear?—that is, in certain neurons whose effects can be observed only under certain conditions How long does the change last? when do the reflex actions cease? and for how long are they absent? When are the reflex times normal again? The experiments undertaken to investigate the problem

were conducted on well-marked pigment-spots of the species *Rana pipiens*, and on higher reflexes, such as the turnover, compensatory, swimming, and equilibrium The spots situated on the head are innervated by cranial, and those on the trunk and legs by spinal nerves The spots chosen were among those that were found to exhibit a certain constancy for long periods in their reaction time to a definite stimulus The stimulus that proved most satisfactory, causing little fatigue or injury to the peripheral nerve-endings, was an 8 per cent pure acetic acid applied with a 3-millimetre square neutral filter-paper The interval that elapsed from the moment the paper was placed until an attempt was made to remove it was taken as the reflex time To prevent injury to the spot it was immediately swabbed after each test with fresh water A control reflex time was secured at different intervals from the corresponding spot on the opposite side of the body

Fixed doses of pure alcohol varying from 10 to 95 per cent were tested and injected into a dorsal lymph sac, after the mean reflex time of a normal frog was ascertained The doses of alcohol varied from 0 05 c c of 15 per cent to 1 c c of 95 per cent, and the reaction time after these and equal amounts of Ringer solution were injected was recorded It was seen that alcohol in such small doses as produced no apparent effect whatever upon the frog have a decided influence upon the reflex centres of some of the cutaneous sense organs—at least in so far that their irritability is lowered, their reaction time slowed, and that when they are once affected by alcohol they do not return to normal reflex time again for some hours, often six to twenty-four hours, depending upon the condition of the frogs and their susceptibility to alcohol From a long series of experiments it was seen that doses less than 0 05 c c of 15 per cent alcohol per 10 grams frog had no more effect than an equal dose of Ringer solution

Beginning with 0 1 c c of 15 per cent, the doses have a depressing effect upon the reflex actions within ten minutes after injecting the alcohol, which effect lasts from one to one and a half hour, though the frog may appear restless But the higher reflexes, such as the turnover, swimming, equilibrium, and compensatory, are not lost until doses of 0 3 c c of 30 per cent are injected Then the frog becomes sluggish, loses its muscle tone, and all spots lose their irritability, and the frog is generally depressed in its action The depressing effect begins within ten minutes after injecting the alcohol, and may last two hours With doses of 0 6 c c of 50 per cent the higher reflexes may be normal again in two hours, but the sensory cutaneous areas are not normal again until the following day, and with this dose tetanic convulsions may appear Doses of 1 c c of 95 per cent proved toxic

We see, therefore, that when the sensory spots fail to respond to the stimulus they do so immediately after injecting the alcohol The depression increases, and is of longer duration with increase of dose The reflex action of the sensory spots is lost before those of the turnover, swimming, compensatory, and equilibrium, and remain absent for longer periods Therefore, even small quantities of alcohol exert a depressing chemical action and never a stimulating increase in reflex time upon certain parts of the nervous system These effects may indirectly affect the muscle tone, vaso-motor and cutaneous thermal reflex actions more or less extensively, depending upon the conditions of the susceptible nervous centres

In considering equivalent doses for man, it is found that, for instance, a dose of 0 1 c c of 15 per cent alcohol, which caused an immediate depression of the reflex time in the cutaneous sensory endings which lasted for about one hour, is equivalent to one pint of sherry or orange or port wine, or 1 13 pint of claret, or two pints of strong beer for a man of average weight

Charts and tables showing the position of the spots, a sample copy of the record of observations, and the tabulation of the reflex time of some of the sensory spots accompanied the paper

---

6 *Nervous Induction in the Paths of the Pressure Sense*
By Max von Frey

If two sensitive points of the skin, so-called pressure spots, are irritated simultaneously, the subject may have the impression of a double stimulus or of a single one In the former case three other effects can be observed, viz, a

mutual influence of the irritations on their intensity, their clearness and location These effects are bound to a certain proximity of the stimuli, and wane with their growing distance There is, for instance, no effect from one hand upon the other, but a pronounced one from one finger upon the next or from a point on the forearm upon any one on the same segment

By comparing a stimulus H given on a finger, say, of the left hand, with another, V, following the first in two seconds on the right, it is possible by adjusting the intensity of the latter to make both equal If now together with H a stimulus N is given on an adjoining finger of the left hand, the succeeding stimulus V appears to the subject much too weak in comparison with H To make V again equal with H, its intensity must be increased, according to the intensity of N, by 80 per cent of the original value

The subject moreover states that the stimulus H, if accompanied by N, loses much of its clearness or distinctness, so that, in comparing it with V, it is difficult to arrive at a definite opinion as to its strength According to the subject, the stimulus H acquires under these circumstances a dim, blunt, or blurred character By repeating the irritation and directing the subject to concentrate his attention as far as possible upon H, the difficulty may be largely overcome

Finally, there is always a tendency of two simultaneous irritations to attract each other, that is to say, the subject is liable to underrate the distance between them, though he can judge it tolerably well, if the two stimuli are given successively The deception is so cogent that it is not overcome by the subject being acquainted with the real position of the irritated spots on the skin If the stimuli are subjectively of equal strength, the dislocation of the corresponding sensations is the same for both, and they appear therefore equally displaced towards the mid-point of the line which connects the spots on the skin If the stimuli are of different intensity, the weaker is always drawn towards the stronger one

The author expressed the opinion that these mutual influences sufficiently explain the well known difference between the successive and simultaneous space threshold or 'Raumschwelle' He entered into a discussion of the processes in the central nervous system by which the described effects may be brought about

---

7 *Binocular and Uniocular Discrimination of Brightness* *By* SHEPHERD DAWSON, *M A , B Sc*

The object of this investigation was the determination and explanation of any differences there may be between uniocular and binocular vision in detecting small differences of brightness The stimulus used was a grey ring on a brighter background, which was formed by rotating in front of a well-lighted, milk-glass screen a sector fitted with a strip which could be placed at any distance from the centre and made to project to any required extent

The observations of four trained observers whose vision is normal show that the power of discriminating is better when both eyes are used than when the better eye is used alone, that the subjects are more certain in their judgments, that the curve representing the correct binocular judgments falls more rapidly than that of the uniocular judgments, and that the ring is located more quickly and more accurately

Material for the explanation of these results is found in the descriptions of the ring and of the processes of finding and locating it The binocular image appears to be due to the psychical fusion of the uniocular images, and in these experiments differs from them most in respect of steadiness That there is probably little or no difference in brightness is demonstrated by the difference in gradient of the curves representing the number of correct judgments at the different intensities (which would necessarily be the same if the difference were only one of brightness), by the occasional detection of as small intensity-differences by one eye as by two, and by the absence of any perceptible difference between the binocular and uniocular images when the ring is clearly perceptible The difference in steadiness is due to the fusion in the binocular image of sensations which are intermittent in their appearance, the result of the fusion being a reduction of the periods of intermittence This explanation is supported, not only by measurements of the periods of intermittence and direct

comparison by the observers, but also by an examination of the criteria by which the objectivity of an impression is determined the most important of these are the steadiness, clearness, and spatial form of the impression, and its relation to subjective activity An impression which fluctuates or appears only momentarily is likely to be ignored or regarded as purely subjective, and it is in this respect that the uniocular images evoked in these experiments differ most from the binocular

8 *Colour-perimetry in the Dark Adapted Eye* *By* Professor Francis Gotch, *F R S*

9 *A Criticism of the Report of the Departmental Committee on Sight Tests* *By* F W Edridge-Green, *M D , F R C S*

This committee was appointed 'To inquire what degree of colour-blindness or defective form-vision in persons holding responsible positions at sea causes them to be incompetent to discharge their duties, and to advise whether any, and if so what, alterations are desirable in the Board of Trade sight tests at present in force for persons serving or intending to serve in the merchant service or in fishing vessels, or in the way in which those tests are applied '

I propose in this criticism to confine myself to the first part of the reference, namely, that dealing with colour-blindness

The committee recommend that the wool test be retained, but further modifications be made of it They suggest that the skeins be divided into groups and a dark brown skein be added The necessity of dealing with the whole of the skeins in doubtful cases was first pointed out by me over twenty years ago The committee have missed the most important points in the use of any test in which wools are employed The first is that the test should contain the confusion-colours of the colour-blind The second that the four chief colour names, red, green, yellow, and blue, should be used If the test do not contain these essentials normal sighted persons will be rejected and colour blind persons passed This I have demonstrated repeatedly It is evident that the committee have not recognised how very defective a man may be and yet pass the official test of the Board of Trade with the ease and rapidity of a normal sighted person In the 'Lancet' of June 22nd I have given an example of a very dangerous case of colour-blindness which I examined for the first time in the presence of Professors F T Trouton and A W Porter Examined with the official test of the Board of Trade the examinee picked out and matched all five test colours, green, rose, red, purple, and orange-yellow, easily and correctly, he did not touch a confusion-colour Examined with the largest aperture of my lantern, measuring $\frac{7}{8}$ of an inch in diameter, at a distance of 20 feet he called red A, nothing and green, yellow, red, red B, white, neutral, green, and green, white and red

The committee have recommended a lantern of their own construction It is absolutely necessary to have means of regulating the luminosity of the light In the lantern suggested by the committee this cannot be done, and many colour-blind persons would learn the sequence and appearance of the colours, and with a little practice would tell all the colours on the method suggested by the committee There are many other essential details which have not been considered, as, for instance, the exact spectroscopic composition of the colours It will be seen from the report that the possibility of dispensing with it and going back to the wool test is mentioned In fact, with the lantern suggested it is quite possible that this might come about

The committee have recommended a classification of colour-blindness based on the flicker method of photometry The classification is based on two assumptions first, that colour blind persons can be classified by measuring the luminosity of their colour sensations, secondly, that it is possible to do this by the flicker method of photometry There is the strongest evidence that neither assumption is justifiable The classification is in direct opposition to the work of the ablest observers

MONDAY, SEPTEMBER 9

Joint Discussion with Section D on the Physiology of Aquatic Organisms

(i) *The Nutrition of Marine Animals by Dissolved Organic Material*

By August Putter

The quantitative determination of the nutritive needs of the lower marine forms by means of metabolism experiments has shown that the views held at the present time, concerning their nourishment, need correction These forms are not nourished, at least to any great extent, by the suspended particles having their origin in marine plants as has been assumed, but by the dissolved organic matter which is found in sea water in great dilution and which is directly absorbed The sea-water itself is therefore for these forms a nutritive medium All recent investigation refutes the belief that the algæ present suffice to nourish most of the prevalent plankton-animals, copepoda, and appendicularia In the sponges, where long-continued metabolism experiments were made, it was demonstrated that suspended particles (only those of minute sizes are capable of passing through the pores) are incapable of supplying the nutritive requirements of these organisms The daily nutritive need at 12° C amounts to about 1 to 1 5 per cent of the body weight The same applies to the rhizostomea, in which, for anatomical reasons, the ingestion of larger particles is impossible, and which have a great food requirement (about 7 per cent of the body-weight per day) Experiments on the actinia and ascidia have shown that dissolved organic matter is absorbed by these forms, and accordingly at the same time disappears from the sea water The method employed was that of the discoloration of permanganate, a method which was employed by Natterer at the Mediterranean Concerning the question of the origin of the dissolved nourishment, it was shown that there was a quantitative increase in the sea-water to which algæ have been added, provided light is permitted to fall upon it, this nutritive material must, therefore, be considered as assimilatory products of the marine algæ

(ii) *The Nutrition, Metabolism, and Respiration of Aquatic Animals*

By Benjamin Moore, *M A* , *D Sc* , *F R S* , Edward Whitley, *M A* , Edward S Edie, *M A* , *and* W J Dakin, *D Sc*

It has been shown that marine animals cannot be nourished either by dissolved organic matter, as supposed by Putter, or by a process of fishing out minute plankton, supposed to be uniformly distributed in the sea-water, but that they must search out either richer veins of plankton or feed on larger portions of vegetable or animal food along the littoral The amount of dissolved organic matter in sea-water is practically negligible, lying well below one milligram per litre of water The plankton removed by silk bolting of 20-mesh, as usually employed for plankton tow nettings, removes only about 0 1 milligram per litre when the water is completely filtered through it, and a Chamberland candle removes about five to six times as much finer plankton, including bacteria These two sources together do not usually exceed one milligram per litre Estimations have been carried out to show the demand for oxidisable food of various species of invertebrates, and it has been found that while the plankton supply, as uniformly distributed, might prove sufficient for such species as sponges and ascidians, it is quite inadequate for crustaceans, molluscs, and echinoderms The relative output of carbon dioxide as compared with intake of oxygen has been ascertained, and it is shown that complete oxidisation of the food does not occur, the respiratory quotient lying well over unity in most cases A metabolic basis for accounting for this peculiar respiratory condition is put forward

The following Papers were then read —

1 *The Neutralisation of Taste* *By* Professor HUGO KRONECKER

2 *Demonstration of a Method for Measuring Phagocytosis* *By* Professor H J HAMBURGER

3 *On the Permeability of Cells and a New Method of Vital Staining (with demonstration) Demonstration of a Method allowing the Permanent Observation of the Results of Vital Staining* *By* Professor LEON ASHER

By aid of this method it was found that the intensity of vital staining in gland cells is dependent on the functional state of the cells Pilocarpin, which is a powerful stimulant of secretion, causes staining to begin much earlier and to be more intense than in a cell not experimentally stimulated, while Atropin, which paralyses for a time secretion, retards the onset of staining, and does not let it reach the degree it attains in a relatively resting cell These facts demonstrate clearly (1) that the greater the activity of the cell, the more does it contain stainable substance, and the greater is the permeability of the cell for the stain, (2) that the same cause, which induces the cell to be more permeable for water and salts, also makes it more permeable for vital stains. The latter fact shows that the solubility in lipoids is neither the only nor the main factor for vital staining Some other facts can be observed which point in the same direction—viz, that Overton's views on vital staining do not give a full explanation

The relationship between permeability of cells and functional state can be demonstrated in the case of sugar Report on the exchange of sugar between blood and cells in the salivary gland During activity sugar goes from the cell to the blood, during rest, in the opposite direction This sugar does not arise from glycogen The observations on the salivary gland prove that sugar, which is insoluble in lipoids, permeates the protoplasm of the cell This fact is an argument in favour of the view that neither in other places is it necessary to invoke *inter*-epithelial permeability

Comparisons of the narcosis of heart muscle, rich in lipoids, and of the skeletal muscle, poor in lipoids, show that some narcotics do not follow the rule of Overton and H Meyer Alcohol and ether narcotise skeletal muscle in a lower concentration than the heart muscle The entrance of a halogen atom into the molecule makes a substance markedly more narcotic towards the heart muscle than towards the skeletal muscle This seems to show that chemical action may play a part in narcosis

4 *Kinematographic Demonstration* *By* Professor P HEGER.

5 *The Horizontal-Vertical Illusion* *By* C W. VALENTINE, *B A.*

To most people a vertical line appears longer than a horizontal line of the same length Three psychological theories of this illusion have been found unsatisfactory In some recent experiments it has been found that the illusion was much greater for one eye than for the other. This suggests that a physiological factor is at work Astigmatism could not account for these differences. For one subject was free from astigmatism, and by testing subjects with and without cylindrical lenses it was proved that astigmatism, much greater than that of the other subjects tested, did not cause any difference in the amount of the illusion Now it has been found that a disc appears of different sizes according to the part of the peripheral field of vision it occupies, and there is evidence of magnification of the apparent size in the vertical periphery compared with the horizontal Varia-

tions in retinal qualities then may explain both the horizontal-vertical illusion itself and the difference found between the two eyes, for the retina of one eye may be somewhat different in this respect from the other Practice was found to result in an increase of the illusion, whereas *psychological* illusions have almost invariably been found to *decrease* with practice This increase seems connected with the assumption by the subjects of a more confident 'mechanical' attitude in making their judgments, basing them more and more on immediate sensory data

---

6 *The Guanidine Group in the Protein Molecule*
By Professor A Kossel

We may assume, as is well known, the following linkage of amido-acid within the protein molecule —

$$\begin{array}{l}
\ldots NH-\underset{\displaystyle R}{\underset{|}{CH}}-CO- \vdots\ NH-\underset{\displaystyle R_1}{\underset{|}{CH}}-CO- \vdots\ NH-\underset{\displaystyle R_2}{\underset{|}{CH}}-CO \ldots
\end{array}$$

In the process of hydrolysis, with the entry of water the carbohydrate chain is detached at the positions indicated by the dotted lines, and amido-acids are formed

$$NH_2-\underset{\displaystyle R}{\underset{|}{CH}}-COOH \qquad NH_2-\underset{\displaystyle R_1}{\underset{|}{CH}}-COOH \qquad NH_2-\underset{\displaystyle R_2}{\underset{|}{CH}}-COOH$$

Proceeding from this basis, and working with the simplest proteins—namely, the protamines—I have endeavoured to determine the position of arginin and lysin in the protein molecule Both of these amido-acids contain two amido-groups, and therefore for each of them there are two combining possibilities, according to whether one or both peptid links take part These are represented in the following formulæ for lysin in A_1 and A_2, for arginin in B_1 and B_2 The investigations, which have been carried out in association with Messrs A T Cameron, E L Kennaway, and N Gawrilow, proved that the formulæ A_1 and B_1 represent the combining conditions

The proofs rest chiefly on the characteristic properties of the guanidine group of the arginin molecule This group determines alkaline reaction, but under the conditions defined by Van Slyke gives no reaction with nitrous acid and contains no nitrogen capable of titration by the Sorensen method

$$\begin{array}{ll}
NH\ CH\ CO & NH\ CH\ CO \\
\quad\ \ | & \quad\ \ | \\
\quad\ C_3H_5\ NH_2 & \quad\ C_3H_5\ NH\ CO\ CH\ NH_2 \\
\quad\ \ | & \quad\ \ | \qquad\qquad\qquad\ \ | \\
\quad\ CO\ . & \quad\ CO \qquad\qquad\qquad R \\
\quad (A_1) & \quad (A_2)
\end{array}$$

$$\begin{array}{ll}
\ldots NH\ CH \cdot CO \ldots & .\ NH\ CH\ CO \ldots \\
\qquad\ \ | & \qquad\ \ | \\
\qquad C_3H_6 & \qquad C_3H_6 \\
\qquad\ \ | & \qquad\ \ | \\
\qquad NH & \qquad NH \\
\qquad\ \ | & \qquad\ \ | \\
\qquad CNH & \qquad CNH \\
\qquad\ \ | & \qquad\ \ | \\
\qquad NH_2 & \qquad NH \cdot CO \cdot CH-NH_2 \\
 & \qquad\qquad\qquad\quad\ | \\
 & \qquad\qquad\qquad\quad R \\
\qquad (B_1) & \qquad (B_2)
\end{array}$$

Those protamines or proteins which contain no lysin, namely, protamines of the salmin group, also zein, hordein, &c , give no evidence, so far as has been investigated, of nitrogen titratable by formol The presence of such lysin (in the protein molecule) can be recognised by the development of N in the Van Slyke procedure and by the titration with formol These last-named investigations have been carried out with the assistance of N Gawrilow

---

7 *The Metabolism of Arginin Effects on the Formation of Creatin and Creatinin* By Professor W H Thompson, *M D*

Arginin, prepared from herring sperma by the method of Kossel, was administered to dogs, both by feeding and by hypodermic injection, in doses of two grammes of the carbonate, neutralised by adding hydrochloric acid

The output in the urine, of total nitrogen, urea nitrogen, ammonia nitrogen, and, in two cases, of amino-acid nitrogen was estimated The results in these respects confirmed previous observations published by the author [1]

In addition, the excretion of preformed and total creatinin, *i e* , creatinin and creatin, was also determined by the Folin method

The experiments fall into two series Series A, in which arginin chloride was given alone, series B, in which it was combined with an equimolecular amount of methyl citrate The effects of methyl citrate administered without arginin were also observed The results are given in the following tables, the figures indicating an increase or decrease per cent (decrease expressed by minus sign) above those of a preliminary average period —

I *Effect on Preformed Creatinin.*

Observation	Feeding	Injection	Day After
	Series A, Arginin Alone.		
	Per cent	Per cent	Per cent
1	1 0	**15 2**	10
2	— 3·5	**20 6**	3 6
3	6 0	**19 0**	9 1
	Series B, Arginin and Methyl Citrate		
4	— 9·3	6·5	0 7
5	— 4 8	11·0	—

II *Effect on the Total Creatinin* (i.e , *Creatinin and Creatin*)

Observation	Feeding	Injection	Day After
	Series A, Arginin Alone		
	Per cent	Per cent	Per cent
1	6·8	**30·2**	10 3
2	— 5·3	**21 3**	— 1·5
3	14·0	**29 0**	12 1
	Series B, Arginin and Methyl Citrate		
4	— 3 0	**63 8**	+ 45
5	Nil	7 1	—

Arginin therefore when injected causes an increase in the excretion of creatinin in the urine and also an excretion of creatin

It was found that when methyl citrate alone was given there was, in one case

[1] *Journal of Physiology,* vol xxxii , p 137; *Ibid Proc Physiol. Soc.,* p. xxii ; also vol. xxxiii , p. 106.

at least, an increase in the excretion of both creatinin and creatin The following table shows this —

Effects of Methyl Citrate.

Observation.	Preformed Creatinin		Total Creatinin	
	Feeding	Injection	Feeding	Injection
	Per cent	Per cent	Per cent	Per cent
3*a*	Nil	Nil	Nil	Nil
4*a*	11 5	21 2	2 2	16 5
5*a*	3 6	3 4	1·1	1 8

The general conclusion is that while the greater part of the arginin administered by *injection* is transformed into urea, some of it appears to be converted into creatin in the dog, and part of this latter to be excreted in the urine as creatinin and creatin The amount thus excreted was considerably increased (in one observation) by a simultaneous *injection* of methyl citrate *Feeding* with methyl citrate in this experiment reduced the output of creatinin and creatin In two other cases feeding with the citrate had no influence

The proportion of arginin nitrogen which reappeared as creatin was, in observation 1, 7 per cent , in observation 2, 6 5 per cent , in observation 3, 6 per cent , in observation 4, 16 per cent The effects here given for arginin and methyl citrate are obtained by deducting the effects of methyl citrate alone, in each experiment, from the total effects of the combined substances

---

8 *The Action of the Corpus Luteum on Metabolism* *By* W Sack

---

9 *Pulmonary Gaseous Exchange in Apnœa* *By* T H Milroy, *M D*

The apnœa which is produced in animals by forced pulmonary ventilation with air is evidently independent of the degree and rate of distension of the lungs so long as the total amount of air driven through the lungs remains the same After freezing the vagi, apnœa can be produced in the same way as with the vagi intact This period of apnœa can be markedly altered by replacing the air in the lungs at the close of the pumping by various gas mixtures In all cases where gas mixtures rich in oxygen are employed in this way, the duration of apnœa is markedly lengthened, in fact, the increase so produced is as great as if the ventilation throughout had been carried out with the mixture On the other hand, gas mixtures which contain amounts of carbonic acid greater than that present in ordinary air produce shortening of the period of apnœa As the carbonic acid in the gas mixture is raised, a point is at last reached when there is at first a loss in the carbonic acid present in the alveolar air, this point evidently indicating that percentage of carbonic acid which corresponds to a partial pressure of that gas above that present in the alveolar air at the beginning of apnœa With gas mixtures which contain 10 per cent or more carbonic acid breathing starts very shortly after cessation of ventilation When the air in the lungs after prolonged ventilation is replaced by nitrogen there pass out into the alveolar air both oxygen and carbonic acid The oxygen which passes out under those conditions does not rise above four per cent , nor the carbonic acid above a slightly lower limit In all cases where oxygen or air is left in the alveoli at the outset of apnœa, the consumption of oxygen takes place more rapidly than the excretion of carbonic acid, the respiratory quotient in the case where air is used being from 0 3 to 0 4 The passage out of carbonic acid from blood to alveolar gas mixtures seems to be mainly if not entirely dependent upon the difference of the pressure of that gas in blood and alveoli, and not upon the nature of the gas mixture in the alveoli Thus carbonic acid passes out practically at the same rate from blood in lungs to alveolar gas mixtures, be those

composed of nitrogen or oxygen or such other gas mixtures as are free from carbonic acid Everything points to the gaseous exchange during the condition of apnœa being due to physical causes, namely, differences of pressure between the gases of the alveolar air and those in the pulmonary blood

TUESDAY, SEPTEMBER 10

Joint Discussion with Section M on Animal Nutrition —See p 742

The following Papers were then read —

1 *Dynamic Centres in their relation to Life, and particularly to Karyokinesis* *By* Professor LEDUC

2 *The Relationship of the Adrenal Glands to the Sugar Content of the Blood* *By* Professor J J R MACLEOD

3 *Physical Chemistry of Muscle Plasma* *By* Professor FIL BOTAZZI

4 *The General Condition of the Spinal Vaso-motor Paths in Spinal Shock* *By* Professor F H PIKE

5 *The Rôle of Memory in Animal Behaviour*
By J L McINTYRE, *M A* , *D Sc*

The question of the function of memory in animal behaviour is a crucial one in regard to the part played by mind and consciousness generally in animals The existence of mental processes cannot be verified except by observations or experiments showing the influence of past experience upon present action Similarly, the more complex forms of consciousness are only inferred from the more intricate, more rapid, or more extended processes of memory which the actions seem to imply

It has been urged that such observations, in the case of animals, neither do nor can prove anything more than 'organic memory,' by which is meant, for example, the formation, persistence, and possible re excitation of connections in the nerve centres or analogous parts of the organism, that the use of terms implying consciousness of any kind in the explanation of animal behaviour is unscientific, that the existence of conscious processes in animals is an unverifiable and also an unnecessary hypothesis, that since known physical and chemical causes are sufficient to account for the phenomena in question, the use of psychological terms and the making of psychological conclusions is mere superstition, and comparative psychology must be denied the right 'to call itself a science '

This paper is an attempt to define and illustrate, with regard to the question of memory, the point of view of Comparative Psychology As a biological science it is concerned primarily with animal behaviour, and the description of such behaviour in physical terms—*i e* , in terms of organism, stimuli, and reactions —is an essential preliminary But its special problem is the evolution of mind—the direction, the stages, and the conditions on which the transition from one stage of the evolution to another depends Wherever animal behaviour is not a rigid, fixed, and uniform response to definite stimuli from the environment as in tropisms and in reflex actions of the 'absolute ' type, but is modifiable by the individual on the ground of, or in reference to, previous experience—there we must assume, if not a stage at least a condition of the evolution of memory 'Memory,' however, is a term that covers several processes usually distinguished

from each other in psychology—the formation of habit, recognition, mental anticipation, and recollection It is shown that the continuity between these processes or forms in the development of memory in the child is paralleled by a similar continuity, and by a like gradual advance from one to the other, in the corresponding behaviour of animals The chief question dealt with is that of the existence of mental imagery or 'free ideas' in animals, their biological function, their origin, and the tests that indicate their presence

---

6 *Note on the Relation between the Effects of Strophantine and the Salts of Ringer Solution* By Professor Dr O Loewi

A heart perfused with a Ringer solution without lime stops much earlier than when perfused with a Ringer solution without lime and without potassium By adding strophantine to a Ringer solution without lime the heart works much longer (about two hours against 30 seconds) than without strophantine, but adding strophantine to a Ringer solution without lime and without potassium the heart beats much shorter (only 30 minutes against 1 hour 30 minutes) than without strophantine

Therefore, there must exist a functional antagonism between the effects of potassium and strophantine strophantine counteracts the potassium effect, so added to a Ringer solution without lime it restores the heart, and potassium counteracts the strophantine effect, so strophantine added to a Ringer solution without lime and without potassium weakens the heart

---

7 *The Prevention of Mental Degeneracy* By R R Rentoul, *M D*

The paper discussed the present amount of mental degeneracy, and the prevention of mental degeneracy by the following methods (1) Compulsory notification of all mental and physical degenerates (2) Compulsory and voluntary surgical sterilisation of mental and physical degenerates (3) Pre nuptial medical certificate of good physical and mental health (4) Making it illegal for any person to issue a permit to marry without obtaining a certificate of good health from the applicants (5) Making it illegal for any clergyman, registrar, or other person to join in marriage any physical or mental degenerate unless the woman is over fifty years of age, or unless sterilised (6) Making it illegal for any *sane* person to marry a degenerate, and to make such marriage null and void (7) Taxation of bachelors (8) Taxation of sterile marriages (9) Proceeds to go to couples with income under £450 per annum who bring up the largest number of physically and mentally healthy children (10) Petitioning her Majesty to institute a Royal Order of maternity (11) Physical degeneration

---

8 *A Plea for Regeneration* By Rev James Marchant

Since the discussion at the British Association meeting at Cambridge in 1905 the subject of physical degeneration has been kept continuously before pu attention There is another paper in this Section upon it May the writer humbly crave permission simply to sound another note? His plea is vague and idealistic, but he hopes it is at least opportune *De*generation, whatever form it takes—fatty, or generally physical—whether attacking the individual or the race, in a physiological or mystical sense, is not peculiar to this age And the fact of *re*-generation—by which the writer desires to oust the unfortunately too easily credited belief in degeneration—is well known to science The local death of some tissues, for instance, as the writer first heard his revered tutor, the late Professor T H Huxley, say, is often followed by 'regeneration' Regeneration in the animal and vegetable kingdoms—for example, the olive tree possesses almost exhaustless capacities of reconstruction—and even in men and races, in no merely metaphorical sense, is an old truth The term regeneration covers a series of facts as well recognised in physiology as in religion, which has claimed peculiar use of the doctrine from time immemorial

But if the belief in regeneration is not novel, the application of it to the race

at a time when belief in degeneration has seized upon the public imagination and the air is full of misgivings about our physical, not to say mental and spiritual, future is, I believe, a primary duty of physiologists and biologists, and of every one of us who has not lost faith in our ultimate recovery from the prevailing nervous attack. As from the renewed life of individual cells is built up the life of tissue and organism, so from the rejuvenated life of the whole social organism the racial life is renewed. Life, more life and ever persistent, is the keynote of the philosophy which is sounding the knell of nineteenth century materialism, and even of the transfigured realism of Herbert Spencer. The old conception of vitalism which sought to account for vital phenomena, which is the ultimate aim of physiology, by 'vital force' or spirit is being revived, albeit in a new incarnation. Creative vitalism (which must assume the physiological basis of life to be persistent) is the thought at the basis of eugenics, which just now is happily concentrating upon the few patent facts of heredity, and urging the legislature to protect the race from the perpetuation of demonstrably doomed lives.

The apparent Irishism that life tends to live, that degeneration may be overtaken and overcome by regeneration, needs to be re-emphasised as a vital truth of science. The whole advance of medicine means this conquest or it means worse than nothing. The causes of the vital phenomena of life, although still very far from being even approximately understood, are slowly revealing themselves, perhaps through the very facts of physical deterioration (a truer word to use in this connection than degeneration). The struggle for existence (rightly mitigated, let it be said, against the callous and callously expressed desire of some persons to let the struggle do its cruel work of weeding in its own bloody way by war and disease) is probably bringing to the surface defects created by modern industrial conditions. But these defects—which charity seemeth to shelter and perpetuate, but which in the end cannot be saved by any philanthropy—whether of brain or muscle or stature, have not touched the foundations of fertility. *Quantitative* human life, as shown by the falling birth rate in some Western countries, whether the immediate causes be voluntary or not, may seem to be failing, but may it not be only a seeming? What new physiological fact of the reduction of essential fertility has come to light since 1875, when the birth-rate began to fall? Or has any inherent tendency towards a progressive decline in the standard of physique been disclosed? Is it not still true that nearly 90 per cent. are born healthy? And that many of the defects in adults and in school children are due to ignorance and avoidable social conditions? Yea, is it not plain that *qualitative* life (which after all is in fact the only true way of measuring life) is advancing. Look around—east, west, north, south—the general quality and level of life and the possibilities of life are improving. That is a sociological fact, but is not its foundation, whether seen or unseen, physical? May not the full explanation of evolution demand constant regeneration of life? The evolution of society is founded upon it. Philosophy is mere chaft without it. Physiology is concerned with the processes and functions of vital—*i.e.*, *re*-generating—organisms. Religion preaches regeneration unceasingly—apart from it her faith and mission would be mockery.

The cry of regeneration, whether of Nordau in France or less enlightened copyists in England, may serve the useful purpose of warning (and no one doubts, least of all the writer, that there is grave need to be warned of certain disturbing features of this age) and of concentrating remedies upon the active symptoms of deterioration. But the writer pleads that the time has come to turn public attention and popular faith to the more assured belief in regeneration and to throw the potent influences of science, sociology, and religion into this scale. Put men into good physical surroundings, with opportunity to encourage healthy mental, moral, and spiritual development, make them less introspective and self centred, and we shall soon have regeneration.

SECTION K.—BOTANY.

PRESIDENT OF THE SECTION.—PROFESSOR F. KEEBLE, M.A., Sc.D.

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

IT is with more than the normal trepidation natural to presidents that I, who have worked on the border-lines of several biological sciences, undertake the task of addressing the members of this Section. As well might a rogue and snapper-up of unconsidered trifles recite his doggerel songs before a bench of learned magistrates.

Therefore, although I have studied from their works the ways of presidents, and although I shall strive to keep to the path which they have mostly trod, yet should I stray I plead with Autolycus that—

> 'When I wander here and there,
> I then do most go right.'

The addresses which I have consulted show me two alternative models.

I may take all knowledge for my province and discourse on the progress of our science as a whole. This is Ercles' vein, a tyrant's vein. Or as a lover of a department of the science and more condoling, I may confine my Address to a special branch of Botany. Each method has its merits and its drawbacks, and the one is corrective of the other.

The departmental method depicts the tree of knowledge in sympodial symmetry. The branch which the president of one year holds out for our inspection is seen arising from an erstwhile dormant lateral bud far back from the growing point of the branch exhibited by his predecessor. Under the magic of the presidential hands the new branch grows as grows the enchanted mango. Like the lean kine it eats up the fat kine, and by the end of the Address it dominates all other branches.

The general method shows the tree in other guise. As an artist is wont to paint a tree, so the historian draws it on monopodial lines, with branches standing in due subservience to the leader and in strict co-ordination with one another. Together these methods tell the truth, which is that the tree of knowledge grows, like many another broad-leaved tree, by a mixed process of monopodial sequences following upon sympodial developments.

What is to the specialist, and indeed for a space is, the luxuriant predominance of his branch appears in historical perspective but as a new lateral for the extension of all the sub-lateral shoots of science.

Such a new basis for the further growth of all the branches of Botany is provided by the lusty shoot of Mendelism, and after weighing the alternatives, and with the reserves announced already, I propose to try to show that this recent outgrowth of the tree of knowledge is destined not to mar its symmetry, but rather to aid the growth of the whole crown. This, my chief task, should have

been my first care had not an event occurred since the last meeting of this Association which compels me, in common with all botanists, to divert thought from its preoccupation and to look back along the route which our science has travelled during the last few decades

That event, I need not say, was the death of Sir Joseph Hooker, a former president of this Association and twice president of this Section The most venerable and distinguished of British botanists, Sir Joseph Hooker was well-nigh the last survivor of that band of Victorian naturalists who helped to lay the foundations of biology and to disseminate broadcast the knowledge which they made The story of the labours of that group of naturalists—Lyell, Darwin, the Hookers, Wallace, Huxley, Galton, and others scarcely less distinguished—has been told so often that there is no need to retell it now Nor need I recount the work of Hooker His discoveries are known and require no re-enumeration They are incorporated with the common fund of knowledge British botanists will determine, doubtless, to consecrate a special occasion to the commemoration of Hooker's services to science and to the perpetuation of his memory My duty it is to express, on behalf of native botanists and of our guests who honour us with their presence, our sense of loss in the death of Sir Joseph Hooker and our admiring recognition of his achievements

And with the example of that long life devoted until its latest hour to the pursuit of science I would fain address myself forthwith to my special task, but despite my will I find my thoughts enchained in the contemplation of the life and times of Hooker Systematist, explorer, critic, writer, administrator, Sir Joseph was first and last a botanist The versatile Hooker was a specialist

Thus I find myself turned again to the thoughts which vexed my mind at the outset of this Address, urged now to ask outright whether the specialisation of our times has the quality which distinguished that of Hooker and his contemporaries

This is the uneasy phantom that has been haunting me and luring me to the ramparts when I should be wooing my chosen theme It haunts me, refusing to be laid Reason fails to exorcise that ghost Its uneasy presence lingers near me even though I conjure it with specious arguments, urging that these days are days of specialisation *à outrance* that nowadays both in the art and practice part of life we live by the intensive cultivation of small-holdings, that the fields of science are parcelled out in small allotments Were I—a simple officer—the sole subject of this visitation I should attribute it to fantasy, and with Horatio cry 'Tush!' but beside this poor Bernardo, Marcellus, officer and scholar, has likewise seen it 'in the same figure like the King that's dead,' and who may refuse to entertain a ghost presenting this—the highest of credentials?

Therefore I offer it again my arguments, insisting that at least among our elders we have specialists as versatile as any of the Victorians The ghost is not impressed Instead, it rises to a fuller height, and lays its incorporeal finger on the row of volumes which line the shelves above my head My obsequious eye follows the direction, and beholds Lyell's 'Principles,' Darwin's 'Voyage,' Hooker's 'Journal,' Huxley's 'Essays,' Wallace's 'Island Life,' Galton's 'Natural Inheritance,' and the other classics from his clients' pens With the dawn of my comprehension the spectre vanishes, and I am alone, but not in peace The message left with me appears to translate as follows The present generation has become expert in intensive cultivation of scientific knowledge but it has forgotten how to market its produce In the preoccupation of specialisation it neglects the art of expression It sinks the artist in the artizan Each specialist exchanges 'separates'—hateful term—with other specialists, but few among us are on speaking terms with the cultured general public curious to know what science is achieving

The translation into common English of our scientific works is done, like that of foreign classics, too much by hacks and amateurs, and too little by skilled hands The present generation lets its modesty wrong it, for the science of our day is no less full—nay, many times more full—of interest and wonder than that of fifty years ago

Still worse to fail to cultivate the art of expression is to blunt the power of thinking, for the adage 'clear thinking means clear writing' stands though the subject and object be transposed

Such is the nature of the charge which my visitant left with me; and though,

as it must have known, my rough translation fails to convey the sober grace of the original, I think that I shall not be alone in pleading guilty to that charge

Nor perhaps will my fellow-specialists resent an attempt to trace the origin of our lack of literary grace This defect is in part inevitable and in part remediable Inevitable because of the increasingly engrossing nature of scientific investigation, because of the relatively small natural gift of expression which nature has vouchsafed to the English race, and because, as science becomes more complex, its followers think more and more in symbols, and those who think in symbols are apt to write in shorthand The defect is remediable because it is traceable in some measure to the training to which we submit our youth That training neglects too much the literary side of education

As it seems to me, there is a fundamental error in our mode of training men of science The error consists in this that students who come to English Universities are treated in intellectual matters not as youths but as men of mature minds The professorial potter takes the clay as he finds it, and, no matter what its state, fires it forthwith, and lo! in course of time it is converted into earthenware Were the assumption on which he acts well-founded, the method might be justified If our undergraduates were, as we assume they are, well found in general culture, trained already in scientific method, familiar with the language of our fathers, and apt also to read and speak and write some other tongue, then let us take them straightway and bake them in the oven of specialisation

But I at all events have never met those students, and, outside the ranks of genius—which training toucheth not—I believe they do not exist The error, as I conceive it, lies in our failure to apply, in drafting schemes of training, the biological law that as society grows older its young men grow younger Undergraduates call themselves men not solely from a sense of pride, but also in obedience to tradition Centuries ago they went up to the University as men of fifteen or sixteen, now they go up as youths of eighteen or nineteen With respect to moral discipline we are not unforgetful of their youth, but with respect to intellectual education we treat them as though they were grown up Even the saving second subject has, I am told, been discarded from the final honours course Let me give an example in illustration of our methods It is found that a student in his second or third year knows no German, and we advise him to learn it But in what a way, with our tacit approval does he set about the task! So that he may tear the meaning from a scientific text as John Ridd clutched the arm of Carver Doone and tore the muscle out of it as the string comes out of an orange!

This barbarism we permit because we know that it is no barbarism but expediency for a trained workman to take up any tool he needs and to use it as he wills In the elegant language of modern literature 'and what he thought he most required he went and took the same as we'

Yet, unless we hold that mental training is a scholastic fiction and that the teachers' sole business is to supply carefully selected and copious provender for the stuffing of students like Surrey fowls, it must be our care to encourage general as well as special culture in our students

A further criticism which I have to make upon our University methods will seem to some far-fetched We are prone to forget that the twin gifts of youth are enthusiasm and idleness The former we encourage, but the latter, falling within the category of morals we visit with our displeasure There is, however an idleness which is not laziness, but a resting period of the organism tired with the trouble of growing up I could wish that our English Universities understood intellectual liberty as well as German Universities understand it We are apt to mind our sheep too much, and to overrate the virtue of docility

I would plead for more breadth and less special knowledge, for more licensed freedom, a lesser uniformity, a wider search for gifts and a slighter regard for specialist attainments It is never too late for a well-trained mind to master a new subject but he who neglects the substance of education for the shadow of mere knowledge robs himself of half the pleasure of his work and of every chance of greatness

In attempting thus to diagnose a complaint which some may think is non existent I have laid myself open to attack at every point, yet I have a flickering

hope that I may be dealt with after the manner prayed for by a youthful examinee whose paper, which I read, contained the appeal 'Mr Examiner, please temper justice with mercy, for I am so young in mind.' This hope I base upon the facts that modern science has at least taught tolerance, and that I have ever found my botanist colleagues conspicuous for this virtue. They understand that even the most minor among prophets prefers the stake to silence, and their good humour acquiesces in the interchange of *rôles* whereby the martyrdom which should be his is borne by them in listening to his wrathful words.

Anticipation of toleration so undeserved leads me to regret almost that I ever introduced that ghost at all. For now that it has served my purpose I am free to admit that I might have laid it long ago by other and *tu quoque* arts.

I, too, might have pointed to those shelves, and at the sight of Mendel's work it would have vanished with a blush. For with all their gracious gifts the Victorians whose just praises I have sung failed to discover that Mendel was alive among them, and showing a way to solve the problems over which they themselves were puzzling.

The merit of the discovery of the greatness of Mendel's work belongs to our generation, and those of us who had no share in it have at least the right to applaud the discoverers and to score the discovery to our side.

So I may conclude the contrast of Victorian with modern naturalists with the reflection: theirs, the higher meed of culture; ours, perhaps, the greater perspicacity.

If, as I am prepared to maintain, the greatest gift which an experimental science may receive is that of a new, serviceable, general method, then to no man are biologists more indebted than to Mendel, for such a method he gave to our science. If, further, this claim can be established, I am absolved from the task of answering the critics of Mendelian doctrine.

Who does not recollect the answer which John Hunter gave to someone—Jenner, perhaps—who wrote to that great experimenter expressing doubt of the validity of an hypothesis? 'Don't think—try,' was Hunter's fine response.

If it were my purpose to discourse on Mendelian doctrine it would be my duty to carry on that work—like the early builders of that doctrine—with sword in one hand and trowel in the other, and to try in emulation of the pioneers to take an equal joy in using either implement. But my work concerns the method and facts accomplished by its use, and, as I understand philosophy, the writ of criticism does not run in the domain of accomplished fact. A homely illustration will serve to define my attitude. Here is a new knife, and there an old loaf, the crust of which has turned the edge of other implements. If with this knife I cut that loaf, it is idle to tell me that my knife is blunt. One form of criticism, and one only, is valid in such circumstances, and that is the constructive criticism of offering a better instrument. If I want bread, and Mendel's knife can give it to me, I shall go on cutting, indifferent to the stones of destructive criticism.

My business, therefore, is to meet criticism not by dialectics, but by confronting it with the facts accomplished by this method and by showing that its use opens new pathways on the borders of the unknown.

Now, if we scrutinise the method of Mendelian research, we may see that there can be no criticism of it.

Give a chemist a complex mixture of many compounds to describe: how does he proceed? The chemist sorts out the ingredients and submits them severally to analysis. Such, also, is the method of the Mendelian analyst. Give him that complex mixture which is called an individual, and he sorts out the ingredients and submits them to analysis. Ask him how two complex mixtures behave when they are bred together, and he re-defines the question in such terms that it ceases to be enigmatical, and becomes susceptible of solution by experiment.

I am not concerned to claim for the Mendelian method the exclusive possession of these virtues. All I claim is that for the work of making a physiological analysis of individuals, and of thereby establishing a physiological classification of plants and animals, the Mendelian method has proved its value. It effects the service by a simultaneous analysis of germ and soma.

but by indirect methods. For so long as the physical nature of living substance remains unknown we can scarcely hope to resolve an individual into its physical components. All that can be done is to make comparative analyses of individuals and to discover how their several components differ from one another.

For our present purpose we may represent the individual by an equation:—

$$\text{Individual} = x + c,$$

where c represents the sum of a long series of characters of the individual and x an imaginary or real individual groundwork left after all the Mendelian characters—the sum of which is c—have been removed by analysis from the individual. The Mendelian method is concerned directly with the resolution of c into its components. Indirectly it is concerned also with x, for by the pursuit of the method the full value of c may be determined, and hence that of x may be inferred. This concession made, it is permissible to concentrate our attention on the term c.

Thus the business of the Mendelian is to resolve the complex of characters which is possessed by an individual into its constituent unit characters. As a consequence of this experimental analysis Mendelism is enabled to restate the problem of the behaviour in inheritance of two individuals in these terms:—

The complex of characteristics which distinguishes an individual is the expression of the sum of a long series of characters. As the individual arises from germ cells so each character arises from a germ within the germ cells. Such germs of characters are called factors. When two germ cells unite to form an incipient individual or zygote they bring together the similar factors of a given character—one factor from the one germ cell and the other from the other. As the zygote forms the mature individual, so the paired factors give rise to a character of the individual.

The body characters are the flowers of the factorial seeds implanted in the germ cells.

Some characters are simple and derive from one pair of factors only; others are of an ascending order of complexity and may be traced to the co-operative agency of two, or more than two, pairs of factors. In the case of a complex character the determining factors may be unlike one another or they may be alike. Thus two pairs of different factors are required to produce the character of colour in certain flowers; on the other hand, it is at least probable that certain characters are the outcome of repeated doses of the same factorial stimulant. Further, the individual is a dual thing—a double-barrelled gun. Each barrel is loaded with the factorial charge supplied by one of the two gametes by whose union its duality is constituted. Conversely and consequently a gamete or germ cell is, in comparison with the individual, of single and not of dual nature. It has one barrel only, and therefore can carry or give effect to one, and only one, of the two factorial charges with which the individual was supplied at the time of its formation.

Our image of the double-barrelled gun serves also to illustrate the several states in which an individual may find itself with respect to its charge of factors of any given simple body character.

Both barrels of the gun may be loaded. An individual in like state possesses two factorial charges and produces gametes all of which are alike in the possession of one of these factors. Therefore, such an individual when self-fertilised, or mated with its like, produces gametes which are all alike in this respect, and these gametes, fusing in pairs, give rise to individuals which all possess the character in question. Such individuals are homozygous; they breed true to the character.

Neither barrel may be loaded, and an individual in like state is also homozygous. It breeds true to the absence of the character. If a gamete of the former individual meet with one from the latter individual, the resulting zygote is in like case with that of a double barrelled gun of which one chamber only is loaded. The zygote is heterozygous for the character. Unlike the homozygotes, which breed true, the heterozygous individual does not breed true to the character in question.

By the application of the foregoing propositions and a little arithmetic, it may be predicted that the offspring of the heterozygote fall into three groups—

one homozygous for the character, and another heterozygous, and a third homozygous for the absence of the character—and that, further, these types of individuals occur in the proportion of 1 2 1 Needless to say, the prediction is susceptible of verification by experimental breeding from the heterozygote These are Mendelian commonplaces with which I should have hesitated to occupy our time were it not for the fact that I desire to emphasise the epoch making nature of Mendel's method The magic wrought by genius is potent because it is simple The rules of Mendelian method are simple If it be urged that I have broken my promise and strayed from method to doctrine I would ask which of the simple propositions I have stated may be demurred to by any student of biology?

The supreme importance of Mendel's contribution to science consists in this that instead of mixing anything with anything 'in the gruel thick and slab' of a witches' cauldron, he has taught us to cast the horoscope of Fate by the method of genetical analysis of individual characters Thus the first part of the Mendelian restatement of the old problem of Heredity reads Investigate one by one the modes of inheritance of the several characters of an individual Choose for this purpose organisms which are as far as possible alike in all respects except for the character under investigation Carry the experiment to its conclusion, even to the third or fourth generation If uncertain results are obtained, ascertain before discarding the method whether the uncertainty may not be due to the interference of other characters not to be suspected *a priori* of exercising an influence upon the expression of the character under investigation

Who, for example, would suspect a morphological character like thickness of stem of exercising an influence on the time of flowering of a plant? Yet such is the case with the pea (*Pisum sativum*), and there is evidence that when this disturbing influence is removed inheritance of time of flowering follows Mendelian rules

The second part of the restatement of the problem of genetics may be expressed as follows Only by the use of individuals of proved constitution with respect to a given character may the effect of external conditions on organisms be determined The study of variation must be preceded by Mendelian analysis and synthesis Let me illustrate this theme by an example

The species *Primula sinensis*, the Chinese primrose, has given rise to many distinct varieties Among these varieties are some with white flowers and others with magenta, blue, red, or other coloured flowers Each of these varieties may be obtained of florists in a pure strain—that is to say, in a strain which breeds true to flower-character For our immediate purpose we will group these varieties into white and coloured forms

It has been shown, however, that this apparently natural mode of grouping is inadequate to give a correct idea of the genetic constitutions of these races It would seem self evident that the white races differ from the coloured races by the lack of flower-pigment, yet Mendelian analysis demonstrates that there are more subtle differences between the different races These differences become apparent when true-breeding white and coloured plants are crossed with one another, for it is then discovered that two types of white-flowered plants exist, and it is only by their fruits—their offspring—that ye may know them Thus if certain white-flowered races are chosen for the experiment, the result of crossing white and colour is a coloured F_1 generation If certain other white races are used and mated with the coloured form the offspring of the cross all bear white flowers The different genetical behaviours of these heterozygous first generations give the clue to the difference between the two forms of white used as parents In the former case—that in which the first (F_1) generation consists of coloured offspring—the second (F_2) generation, raised by self-fertilising F_1 individuals or by crossing them with one another, consists of coloured white in the proportion of 3 1

Whence we conclude that the white used in this experiment owes its character of whiteness to lack of the pigment-producing factor which is present in the coloured parent race This conclusion is confirmed by the genetical behaviour of the whites of the F_2 generation Such extracted whites breed true to flower-character—that is, give rise to white-flowered offspring only White-flowered races which behave in this manner are termed recessive whites

In the second case—that in which the F_1 generation consists of white-flowered offspring—the F_2 generation, from selfed or intercrossed F_1 plants, consists of three white: one coloured. The coloured offspring breed true. Of the three whites one breeds true to whiteness and the other two give rise, like the white F_1 generation, to three white: one colour. White races which thus impose their whiteness on the offspring of their union with a coloured race are known as dominant whites. Mendelians account for the genetical behaviour of dominant whites by assuming that they carry the character for colour and also a character for colour-inhibition. This hypothesis is amply justified by genetical results. Nevertheless it is an hypothesis which is novel to biology. It propounds a series of questions to the physiologist and biochemist, and in so doing exemplifies the fruitfulness of Mendelism. We shall see immediately whether the biochemist is able to take up this Mendelian challenge and what answer he can give to it.

At present, however, we are concerned to show by an example the necessity of prefacing the study of variation by Mendelian analysis. It was stated just now that the cross, dominant white by colour, results in a white F_1. That statement requires amplification. Grown under normal conditions the F_1 individuals bear pure white flowers, but if grown in somewhat higher temperatures the flowers develop a distinct though pale flush of colour. It is easy to show that the factor for colour is unaffected by the changed conditions, for the flushed F_1 individuals yield offspring of the same kind and in the same proportions as those produced by white F_1 plants.

It is fairly evident that the flushing is produced by the destructive action of heat on the inhibitor. In pre-Mendelian times this response to temperature would have been added without more ado as yet another ornament to dress the window of that old curiosity shop which is stocked with miscellaneous and heterogeneous articles all ticketed with the label 'variation.'

But in the light of Mendelism we may see in this effect of temperature the result of the casting-vote of circumstance on a heterozygous constitution. We may recall instances—as, for example, those provided by the well-known experiments on the effects of high temperatures on insect larvæ—which seem to show that environmental agencies may single out not only characters but also factors for attack. Thus we may begin to cohere in series the hitherto sundered and scattered phenomena of variation.

It is not yet possible to say how much of variation is to be put down to the interplay of characters, or, rather, to the differential effects of external conditions on characters which tend to balance one another; but this at least may be said—that the old and worn controversy on acquired characters was so much waste of words, because the problem purporting to be discussed had never been defined. Like the half of human quarrels, it was a quarrel about words.

It is stated in the books that the formation of peloric (regular) flowers may be induced by uniform illumination. Was the material used in the research homozygous or heterozygous? Does uniform illumination just prevent the unpaired factor from inducing normal growth? If so, what is the effect on the homozygous normal? These are examples of questions which suggest themselves at every turn, and they will abide the answer of experiment. The time is approaching when it will be possible to test the validity of the hypothesis on which the super-hypothesis of natural selection rests apparently secure from verification or disproof.

That hypothesis maintains that everything is in a state of flux; that variation occurs at all times and affects all parts. This may be true of multiple mongrels, of organisms which are heterozygous for many characters. On the other hand, nothing is more surprising than the stability of forms which are pure-bred for a fair number of characters, and it is at all events a suggestion not to be rejected summarily that plants pure bred for a considerable number of characters may exhibit a constancy and stability not usually associated with our ideas of living things.

In any case, it is open to the biologist to provide himself with suitable material wherewith to study the range and scope of variation and to investigate the conditions under which the organism discards old characters and regresses

or acquires new ones and progresses It is open to the Mendelian breeder to standardise creation

Thus in fulfilling the first part of its task—that of defining the pure-bred—the Mendelian method has provided the material for the fulfilment of the second part—namely, the investigation of the conditions which make for the stability and instability of the organism I think the time has come when this latter task might be undertaken on a large scale and with good prospects of success

So far I have played the part of one of those street-corner watchers of the skies who offer a telescope for the inspection of the heavens I have now to take a turn myself, and by means of the binoculars of Mendelism and Physiology survey not the celestial bodies, but certain new features of a small and narrow terrestrial field which this instrument brings within our ken My survey has reference to the phenomena of the pigmentation of plants, and is confined to those presented by the anthocyan or sap pigments to which the colours of many flowers are due

Until recently knowledge of the processes of pigmentation advanced along two main and independent lines One line of advance—that followed with such brilliant success by Bateson and the Cambridge school, as well as by other students of genetics - has led to a wealth of exact knowledge with respect to the factors and characters which determine coloration The other line of advance, pursued with no less brilliant results by Chodat and Bach and by Palladin and his associates, has resulted in a great increase of our understanding of the biochemistry of pigmentation

The merit of being the first to combine the genetical with the biochemical method belongs to Miss Wheldale, to whom, moreover, we owe a good working hypothesis of the nature of the processes involved in pigment formation The work of Palladin and of Chodat and Bach is so well known that I need not review it in any detail To Palladin we owe in large measure the conception that respiration consists in a sequence of enzyme-like actions, the later of which result in oxidations and are ascribed to oxydases To the same observer we owe also the suggestion that chromogens play a part in the oxidations set up by oxydases, and that these colourless chromogens may undergo either alternate oxidation and reduction and so take a continuous part in oxydase action, or undergo permanent oxidation and so constitute the pigments of the plant

Chodat and Bach have given us a serviceable conception of the nature of oxydases According to the Chodat Bach hypothesis oxydases are of dual nature, the complete oxydase consisting of two parts—a peroxydase and an organic peroxide An oxydase reacts with oxidisable reagents, such as guaiacum, to produce a characteristically coloured product Hence these reagents may be termed oxydase reagents Peroxydases react with oxydase reagents only if there be added, as a substitute for the organic peroxide of the complete oxydase, a source of active oxygen in the form of hydrogen peroxide Both oxydases and peroxydases occur in the cells of plants, and may be identified in extracts therefrom

The work of Gortner on the pigments of insects adds confirmation to the view that pigments are the product of the action of oxydase on chromogens Thus he has shown that the black or brown melanin of the integuments of insects is produced by the action of an oxydase, tyrosinase, on some such product of protein hydrolysis as tyrosin

Miss Wheldale's studies have led her to formulate the hypothesis that the anthocyan pigments of plants are the outcome of a series of chemical changes of the following order Glucosides hydrolysed by emulsin yield chromogens which, acted on by oxydases, give rise to anthocyan pigments The difficulty in the way of further advance lay in the unsatisfactory nature of the methods for identifying oxydases derived from plant tissues Hence when we turned our attention to this subject Dr E F Armstrong and I made it our first task to search for means whereby we should be able not only to identify but also to locate, oxydases and peroxydases in plant tissues Clarke had tested already numerous oxydase reagents and found that certain among them are adapted for microchemical use As the result of a considerable number of trials of known reagents we have found that α naphthol and

benzidine are each adapted admirably for the purpose of locating oxydases By means of these reagents we have been able to map out the distribution of oxydase and peroxydase in the flowers and other parts of various plants, and although the work is laborious and the technique as yet imperfect, the results afford strong confirmation of the current hypothesis of the mode of formation of anthocyan pigments This confirmation, however was rendered possible only by reason of the fact that we worked with races of plants bred on Mendelian lines, and hence of known genetic constitutions

Our method of investigation is briefly as follows The oxydase-reagent is used in weak alcoholic solution, the part of the plant to be tested is incubated in the solution for a suitable time, and if no oxydase action takes place—that is, if no characteristic coloration of the tissues occurs—the material is tested for peroxydase by the addition of hydrogen peroxide The method may be employed for intact corollas or petals or for sections of plant-tissues

It is important to mention that the first result of immersing a sap-pigmented tissue in either reagent is the decolorisation of the tissue For example, a corolla of a coloured-flowered race of *Primula sinensis* loses its colour completely after being immersed for an hour or two in either reagent The decolorised corolla, which in the case of *P sinensis* remains colourless, is treated with hydrogen peroxide, with the result that a well-marked peroxydase reaction is obtained The reaction is confined to the non-chlorophyllous parts of the corolla, and does not occur, except in the epidermal hairs, in the region of the yellow or green eye, the tissues of which contain chlorophyll Indeed, there is good reason to believe that chlorophyll inhibits oxydase action

By treating similar flowers with each of our two reagents we find that the actions of α-naphthol and benzidine are, in a considerable measure, supplementary one of the other Thus the lilac-blue α-naphthol reaction is confined or almost confined to the veins of the corolla, the brown benzidine reaction is exhibited by the superficial (epidermal) cells and also by the veins In order to emphasise the facts of distribution we speak of the peroxydases of *P sinensis* as epidermal peroxydase and bundle oxydase The former occurs in the epidermis and in the epidermal hairs, the latter in the bundle sheath which accompanies the veins

Similarly, if sections of a stem of *P sinensis* be investigated they are found to contain a superficial peroxydase and a deep-seated peroxydase As the result of remarking the peroxydases, not of any unknown variety taken at hazard, but of the several varieties characterised by constant differences of depth and extent of pigmentation, we have been able to show that the distribution of peroxydase in any one race coincides broadly with the distribution of pigment in the most pigmented races In other words, in *P sinensis* the peroxydase framework for pigmentation occurs throughout the species, and the building of the several colour varieties is determined by the activity of the factor for chromogen production If we conceive of this factor as administered in a series of doses we can form a fair picture of the mode of evolution of the series of varieties characterised by increasing or decreasing amount of pigmentation of their vegetative parts

On turning to investigate the peroxydases in white-flowered races of *P sinensis*, we shall expect to find from analogy with the peroxydases of the stem that these agents of pigment-formation are not lacking from the corollas of recessive whites The application of our reagents shows that this expectation is correct, and that those white-flowered races which lack the factor for colour contain epidermal and bundle peroxydase Hence we conclude that the absence of colour from recessive white flowers is due not to the absence of peroxydase, but to absence of chromogen This conclusion is in conformity with that arrived at previously by Mendelian methods, for, as we have noted already, these methods demonstrate that anthocyan pigmentation of the flower of *P sinensis* depends on the presence of one factor only, and that the absence of pigmentation which is characteristic of recessive whites is due to the absence of that single colour-factor

The result of our investigation of the peroxydases of dominant white flowers is, on the other hand, quite different from that given by recessive whites When corollas of dominant white races are treated with α-naphthol

or benzidine and subsequently with hydrogen peroxide, they show no sign of peroxydase neither in epidermis nor in bundles Hence such flowers either lack peroxydase or else they contain a substance which inhibits peroxydase from exercising its oxidizing action on our oxydase-indicators

That oxydases may be inhibited *in vitro* has been demonstrated already by Gortner, who has shown that the addition of certain phenolic compounds—orcin, resorcin, etc —prevents tyrosinase from exercising its characteristic action upon tyrosin

Assuming that an inhibitor of peroxydase occurs in dominant white flowers, it may be supposed to act either by destroying peroxydase or by setting up conditions under which the activity of peroxydase is arrested Assuming further that the inhibitor acts in the latter way, it follows that if means of destroying or removing the inhibitor be discovered and employed, the peroxydase released from the inhibitory grip should be free to effect the oxidation of our reagents

This train of reasoning gave us a point of departure for experiment Starting from this point Dr Armstrong and I have found in hydrogen cyanide a means of removing peroxydase-inhibition Thus if dominant white flowers are immersed in a 0 4 per cent solution of hydrogen cyanide for twenty-four hours, washed, and treated with either of our reagents together with hydrogen peroxide, pronounced peroxydase reactions are obtained, both in the epidermal and bundle tissues of the corolla Carbon dioxide in aqueous solution produces a like, albeit a less pronounced, effect

Now, it so happened that we had at our disposal a race of Primulas, the flowers of which lend themselves peculiarly well to the purpose of confirming these observations The race in question is characterised by blue flowers with fairly symmetrically placed paired white patches on each petal We have reason to believe from the known ancestry of this race that these white patches are produced by a localised inhibitor

Corollas of these flowers treated with α-naphthol or benzidine become quite colourless When, however, hydrogen peroxide is added the natural pattern is restored The parts originally blue are stained lilac-blue or brown according to the reagent used, and the inhibitory patches stand out as in the intact flower as white areas on the coloured ground

If instead of submitting the particoloured flowers directly to the oxydase reagent, they are treated first with hydrogen cyanide, and then treated with the reagent and subsequently with hydrogen peroxide, the inhibition located in the white areas is found to have been removed, and the peroxydase reaction is produced over blue and white areas alike

Hence the Mendelian hypothesis of the inhibitory nature of dominant whites is confirmed by biochemical methods Moreover, these methods demonstrate that the inhibitor acts not by destroying but by preventing the action of oxydase upon the chromogen

There are many other aspects presented by the phenomena of oxydase distribution in *P sinensis* and other plants which we have investigated Some I may enumerate, but lack of time must be my excuse for not dealing fully with any of them

The close proximity in the flower of the superficial and deep oxydases suggests that the latter may co-operate with the former in producing flower pigments This possibility entails the hypothesis of a translocation of oxydase from the region in which it is secreted to that in which it acts, and there are not a few facts which are in favour of this view, for example, the lines of deep colour which occur along the veins of many flowers, the frequency with which the walls of cells appear to contain oxydase, the occurrence of oxydase in the mesophyll cells which adjoin the bundle sheath, and the evidence provided by the mutual influence of stock and scion in grafted plants and in graft hybrids Though these and other subjects must be passed over, I cannot resist giving what appears to me to be the most elegant mode of demonstrating the relation between oxydases and pigmentation which we have as yet observed The plant which has served for this purpose is the Sweet William (*Dianthus barbatus*), and any of the old-fashioned races of this plant common in cottage gardens suffices, provided that it be an ever-sporting race Such a race is known by the fact that it bears, on one and the same head, flowers of different

colours. The race which we have used is very sporting, a single plant bearing in one inflorescence deep magenta, pale magenta, white with limited rose flush, and all but pure white flowers.

If a petal of each of these flowers be treated with the benzidine reagent, it is found that the extent and amount of the oxydase reaction, as measured by the distribution and depth of brown coloration indicative of oxydase, coincide precisely with the extent and amount of pigmentation The full-coloured petal gives a uniform deep brown reaction, the light magenta a uniform but paler reaction, the petal with a limited rosy flush gives a slight reaction, limited to the pigmented area, and the all-but-white petal gives none but the slightest reaction, and that only in the part of the petal which contained traces of pigment Thus—unless the results are due to a partial inhibition which has eluded our attempts at demonstration—it would seem established that the ever-sporting habit is due to differences in the amount of oxydase in the diversely coloured flowers

The Sweet William is also noteworthy in that it contains white races, some of which give an oxydase reaction in their petals and some of which give no oxydase reaction Breeding experiments now in progress will decide whether or no these white races, like those of Sweet Peas investigated by Bateson and Punnett, mated together yield coloured progeny If so the factors for colour, long wandering yet not lost, which meet again in reversionary coloured crossbreeds, may prove to be a chromogen factor and an oxydase factor

Finally a brief reference must be made to our observations on the periodic fluctuation of oxydase in plants Various observers have noticed that plant tissues give the peroxydase reaction much more generally than the oxydase reaction The observations now to be described indicate that this is due to the greater stability of peroxydase as compared with the organic peroxide

Under certain circumstances a tissue which gives only the peroxydase reaction may exhibit the direct oxydase reaction Moreover, the extent of the peroxydase reaction, as judged by the depth of coloration of the reagent, varies in similar plants at different times

Enquiry into the meaning of these fluctuations led us to the discovery that the nature and amount of oxydase contained in a plant tissue varies in an orderly manner according to external conditions

Among the conditions which determine this fluctuation are light and darkness Plants subjected to normal illumination possess less oxydase than those which are kept in darkness After one or two days' exposure to darkness plants of *P sinensis* contain more peroxydase than sister plants kept under normal conditions of illumination Moreover, after such an exposure to darkness tissues which under normal conditions give only peroxydase-reactions yield distinct oxydase-reactions

Whether these phenomena are general among plants we are not yet in a position to say, but repeated experiment enables us to vouch for them in the case of *P sinensis* Should the results of similar investigations with other plants show that this diurnal variation of the oxydase content of plant tissues is of general occurrence, we may perhaps discover therein the means whereby many of the phenomena of periodicity exhibited by plants are maintained and regulated We know that the light and darkness of the day and night set up rhythms in the plant, for example, that the leaves of various plants assume nocturnal and diurnal positions We know further that the rhythm thus established may be maintained for a certain time under uniform conditions of illumination This is the case with the Sensitive plant and many another

Animals also exhibit a like periodicity. Thus some years ago Dr Gamble and I showed that certain shrimp like animals, *Hippolyte varians,* roll up their brilliant chromatophores at night and assume a sky blue colour When daylight comes they put on their daytime dress by spreading out the pigment of their chromatophores in far-reaching superficial networks Kept in the dark these animals retain for many days this periodic habit, and when the hour of night arrives, although they have no light to tell it by, they lay aside their daily garb and put on the uniform of night. So also the plant-animal *Convoluta roscoffensis,* which lives on the seashore, orders its behaviour by the sun and moon. It lies on the sand till the waves of the making tide are upon it, and

then descends to security and darkness. When the tide recedes it rises to the light Even the uncongenial surroundings of a tea-cup and a laboratory fail to break this habit, for in these surroundings its uprisings and down-lyings keep time with the tides

To one who has scrutinised with perplexed mind these mysteries of biology the speculation may be permitted that light and darkness may work these wonders through the control of chemical agents such as oxydases But though it be legitimate to make a speculation of this kind it is idle to hunt the unknown to the death without the lethal weapon of experiment, and so I leave it for the present unpursued, and with it my Address We have it on the authority of a poet and philosopher that to the traveller on a lonely road each bush becomes a bear, and I am not oblivious of the fact that oxydases have obtruded themselves with a certain obstinacy in the course of my Address Nevertheless, obsession has its uses and significance, for it is the after effect of enthusiasm, and though I have dealt, perhaps at undue length, with special problems and with suggestions, I venture to think that I have made out my case for the opportuneness of an *entente cordiale* between Physiology and Mendelism

---

The following Papers were read —

1 *On the Blechnum-Woodwardia-Doodya Series of Ferns, with Remarks on the various Phyletic Origin of Indusia in the Filicales Lantern By* Professor F O Bower

2 *The Upper Devonian Beds of Kiltorcan, Co Kilkenny The Stem of* Archæopteris Hibernica *Forbes Sp By* Professor T. Johnson, *D Sc*

The genus Archæopteris has been recorded from the Upper Devonian beds of Kiltorcan (Co Kilkenny), N.E Scotland, Bear Island, N E America, Central Europe, &c , but has been hitherto known only by its fine isolated sterile and fertile fronds The Department of Agriculture and Technical Instruction recently authorised a re-examination of the fossil beds at Kiltorcan, now unhappily being demolished for road-mending The author, with Mr I Rogers, spent a week this summer in quarrying the beds, and found several specimens of stems of Archæopteris, with the basal parts of the fronds attached The stem, 3 cm wide, winged by the decurrent bases of the leaves, shows ridges corresponding to the grooves on the adaxial side of the sheathing stipular base of the frond One or two specimens, Marattiaceous in habit, are strikingly suggestive of *Caulopteris Lockwoodi* from the Upper Devonian beds of New York (Gilboa), as figured by Dawson In other specimens the internodes, as much as 5 cm long, are more clearly marked It is possible that these stems, with longer internodes, belong to *Sphenopteris Hookeri*, Bailey The stems were found in the same slabs as the foliage, but naked rachides only were found in actual continuity with the stem

3 *Alethopteris Foliage with Seed* (Trigonocarpon) *By* Professor T Johnson, *D Sc*

The slabs show typical casts of the seed of *Trigonocarpon*, 2 cm wide, 3 cm long They are roughly comparable to a plum stone in appearance, but are beaked and regularly ridged In one case the cast of the seed appears to be connected with a pinna of *Alethopteris lonchitica*, carrying pinnules on one side only, the seed being attached to the other, apparently otherwise, naked side In another case the seed is better shown with typical *Alethopteris* foliage at its base The specimens tend to confirm the view held by many palæobotanists that *Alethopteris* is the foliage and *Trigonocarpon* the seed of Pteridosperm *Medullosa* The material was obtained this summer in the coal beds of Killenaule, Co Tipperary, by Mr I Rogers, collecting for the Geological Survey of Ireland and the Royal College of Science, Dublin.

4. *On the Structure of* Lepidostrobus laminatus *sp nov.* *By* Agnes Arber, *D Sc , F L S.*

Lepidostrobus laminatus is a new species based upon a single section of a cone, which is believed to have been derived from one of the coal-balls of the British coal-measures Its most marked peculiarity is the presence of sterile processes within the sporangium, comparable with those occurring in *L Brownii*, Unger, and in *L Veltheimianus*, Scott, but more definite and elaborate in form

FRIDAY, SEPTEMBER 6

Joint Meeting with Section B on the Biochemistry of Flower Pigments See p 438.

The following Papers were then read —

1 *Experiments in the Origin of Species in the Genus* Hieracium *(Apogamy and Hybridity)* *By* C H Ostenfeld, *Ph D*

During several years I have studied the genus Hieracium, and in particular with regard to its highly polymorphic condition I believe that I am now able to correlate this polymorphy to the apogamy and hybridity that occur in the genus—although it is not permissible to draw any conclusion as to causality between them

In 1903 it was proved by Raunkiaer and myself that many species were apogamic We found that they were able to produce fertile seeds when the flower-heads were ' castrated '—*i e* , when the upper part of the unopened flower-heads were cut away with a razor, thus removing both the anthers and the stigmas

The genus has been divided into three sub-genera (i) Stenotheca, (ii) Archieracium, and (iii) Pilosella The species of Stenotheca investigated were only able to produce fertile seed when normally fertilised, and were quite sterile after castration Polymorphy appears to be absent in this sub-genus Archieracium, on the other hand, is very polymorphic Experiments were made with about sixty-five forms of this sub-genus, and it was found that they are nearly all more or less apogamic The majority are absolutely so and quite incapable of fertilisation A few, although apogamic, are still capable of being fertilised, and in two only—*H umbellatum* and *H virga aurea*—does fertilisation appear to be an actual necessity

If the pollen of the sexual species of the genus be examined all the grains are normal in appearance, but in the apogamic Archieracia some species have pollen which has degenerated to a few yellowish brown lumps, and anthers looking empty In other species, while some pollen-grains are small and evidently not fertile, others are full-sized but nevertheless seem to be incapable of germination

In the sub-genus Pilosella some species are sexual while others are apogamic, but not absolutely so, their pollen being mostly fertile

As regards the origin of new forms, these must arise (i) by hereditary variation of already existing species, (ii) by hybridisation, and (iii) by a combination of i and ii From experiments made by crossing the more or less sexual species of the sub-genus Pilosella, the first generation F_1 is heterogeneous, in contrast to the ordinary rule for hybrids Some individuals are like the mother, having been produced apogamously, while others are evidently hybrids, although each of them differs from the others. The subsequent generations F_2 and F_3 are homogeneous, and like their respective parents in the F_1 generation. Because the hybrids, if not quite sterile, are apogamic. In consequence the new forms, which arise by means of crossing, are at once quite constant.

It is obvious that the origin of new forms in the absolutely apogamic species

of the sub-genus Archieracium must be due to some other cause. Some of these forms have a very limited distribution, and their areas fall within the areas of nearly related but more widely distributed species. They seem to have a centre from which their distribution extends, all things pointing to this centre as the place where the form in question has arisen. Further, a few experiments hitherto carried out have given, in some cultures, one aberrant individual among 200 or 300 typical ones. Such forms must have arisen by hereditary (single) variations (so-called mutations), which, because of their apogamy, are at once fixed, since they cannot become mixed by crossing with the original form. Such variations may be classed under bud-mutations, as no fertilisation is required for their appearance.

---

2. Geum intermedium (*Ehr.*) *and its Segregates.*
By Professor F. E. Weiss, *D.Sc.*

Geum intermedium was the name given by Ehrhart to the plant now generally recognised as the hybrid between *Geum urbanum*, the Common Avens or Herb-Bennet and *Geum rivale*, the Water Avens. It is a natural hybrid, occurring not infrequently in localities where both its parents are common, and it can also readily be obtained by pollinating the Common Avens with the pollen of the Water Avens. The hybrid, as the name given to it indicates, exhibits a remarkable blending of certain distinctive characters of its parents.

The intermediate condition is not only found in such very obvious features as the position, size, and colour of the flowers, but also, as Macfarlane has pointed out, in certain anatomical characters, and in the size of the pollen grains. The apparent intermediate condition of the colour of the petals is due to the fact that the hybrid has inherited both the anthocyanin, which is found in the epidermal cells of the petals of *Geum rivale* and the yellow plastids of *Geum urbanum*. Here, then, we have no true intermediate condition but the inheritance of two characters, one belonging to each parent.

The presence of anthocyanin in the flower stalk and sepals of *Geum intermedium* indicates that this is a dominant character since anthocyanin is entirely absent from these organs in *Geum urbanum*, and is quite as marked a feature of the hybrid as of *Geum rivale*. On the other hand, one distinctive character of *Geum rivale*—namely, the carpophore carrying the head of fruits beyond the calyx—is entirely absent from the hybrid. This character is probably correlated with the spreading calyx and open flower of the hybrid.

Geum intermedium is perfectly fertile, and I have now a considerable number of offspring, both of the f_2 and the f_3 generations. A few of the second filial generation (f_2) resemble the normal hybrid type of the f_1 generation, but the majority of plants differ from the latter and also among themselves, indicating that a segregation of characters has taken place.

As a number of my plants have not yet flowered I cannot give any definite numerical ratios of inheritance of the various characters, but I may say that the following characters show segregation in the f_2 generation :—

(1) *Curvature of Peduncle.*—This character, which shows an intermediate condition in the hybrid, disappears entirely in a few of the second filial generation (f_2), while in others it has become as accentuated as it is in *Geum rivale* but often associated with a perfectly green peduncle and calyx, and flowers which are almost pure yellow.

(2) *Presence of Anthocyanin.*—This character, as follows from the above statement, is not correlated with curvature of the peduncle. Dominant in the f_1 generation, it disappears in some of the individuals of the f_2 generation.

(3) *Calyx.*—While the hybrid has an expanded calyx intermediate between the closed calyx of *Geum rivale* and the reflexed calyx of *Geum urbanum*, in the f_2 generation both reflexed and closed calyces have made their appearance, the former sometimes with orange, sometimes with yellow petals, the latter so far only with orange or with pink petals. There would therefore seem to be some indication of correlation of characters.

(4) *Colour of Petals.*—The majority of flowers in the f_2 generation retain both a certain amount of yellow and also some of the anthocyanin in the epidermal cells. Some few resemble *Geum intermedium* very closely, but in others the

relative amounts of red and yellow differ very considerably, so that a great range of colour forms have appeared Some plants have lost their yellow plastids, but the anthocyanin is sometimes present in very small quantity, so that the flowers are pale pink in colour, the anthocyanin being mainly present in the veins Some plants have flowers which are nearly pure yellow, the anthocyanin only making its appearance towards the end of the flowering period In one case the flowers are devoid of both yellow plastids or anthocyanin during the early stages of flowering, but towards the close of the flowering period, anthocyanin makes its appearance at the back of the petals and they become pink in colour

(5) *Shape of Petals*—In the f_2 generation a considerable variation makes itself manifest in the shape of the petals, both ob cordate and ob ovate forms being noted

Differences in the length of the claw are also apparent

So far no distinct carpophore has been noted in plants of the f_2 generation

The offspring of three of the segregates of the f_2 generation have been raised by self-pollination, and several have flowered this year So far they have shown little or no variation from their f_2 progenitors

My observations and cultures lead me to the conclusion that there is very little variation in the f_1 generation (the *Geum intermedium typicum* of some authors), and that some at least of the forms named and described by Rouy in his 'Flore de France,' and by Ascheron and Graebner in their Synopsis of the European Flora, are segregates produced in the f_2 generation of this hybrid Other forms are undoubtedly due to the crossing of the hybrid with its parents I have obtained these crosses which are intermediate in character between the hybrid and the respective parent, but, as might be expected, with a greater amount of variation than is shown by *Geum intermedium* itself Thus a very complete series of forms can be obtained connecting *Geum urbanum* with *Geum rivale*

3 *The Relation of Beech Forest to Edaphic Factors* By MACGREGOR SKENE, B Sc

In Great Britain natural beech forest is confined to the South of England, and is developed only on chalk A type of beechwood quite distinct from this and belonging to the *heath formation* has a wider distribution, and is found on non-calcareous soil In the North of England and in Scotland the beech cannot be regarded as native, although it has been extensively planted for about two hundred years, and now forms woods which appear to be self maintaining

In Tansley's 'Types of British Vegetation' the true beech-forest of the South of England is classified as an association--*Fagetum sylvaticae calcareum*—of the *plant formation on calcareous soils, sub formation of the chalk* The presence of chalk is thus regarded as the chief factor determining its occurrence

The chief ecological characters of the forest are (1) the intense shade obtaining in the interior and (2) the thick layer of mild humus and dead leaves which clothes the soil The combination of these two factors accounts for the type of ground vegetation Underwood is practically absent, and frequently the soil is quite devoid of an herbaceous flora Where such a flora is present it consists entirely of shade loving plants *Mercurialis perennis* is most abundant and is accompanied by *Sanicula europaea*, *Viola Riviniana*, *V sylvestris*, *V hirta*, *Fragaria vesca*, *Circæa Lutetiana*, several orchids, and the two saprophytes *Neottia Nidus avis* and *Monotropa Hypopitys*

An association which very closely resembles this in all but floristic details occurs at high altitudes in the Cevennes in the South of France Beech forest extends from 2,500 feet upwards, its highest limit not being reached even on peaks of over 5 000 feet Here again we can recognise the leading ecological features of the typical beechwood—intense shade and a thick layer of mild humus Underwood is absent, and the ground vegetation, where present, is composed of shade lovers *Anemone nemorosa* is abundant and locally dominant, along with it occur *Ranunculus aconitifolius*, *Dentaria digitata*, *Asperula odorata*, *Allium ursinum*, *Viola sylvestris*, *Conopodium denudatum*, *Luzula nivea*, *Veronica montana*, *Actæa spicata*, *Neottia Nidus-avis*, and several ferns

This French forest occurs typically on a schist which is conspicuously free

from calcium carbonate Yet it resembles the English forest on chalk exactly, except as regards floristic detail, and the floristic differences are purely geographical in origin, with the exception perhaps of the presence of *Viola hirta* in the English wood, and of the ferns in the French, which may be due to edaphic influences

From the genetic standpoint, too, both are essentially similar, both are stable associations, degenerating, if subjected to the ravages of grazing animals, into similar park- or pasture-land, from which they regenerate themselves if protected by a simple *mise en défense*

It would thus seem necessary to regard the beech-forests of the Cevennes and of the English chalk as associations or sub associations of some one formation and to discard the idea of a *plant-formation on calcareous soils*

---

4 *The Ecology of* Calluna vulgaris
By Miss M Cheveley Rayner, *B Sc*

A starting-point for the experimental work described in this paper was found in the occurrence of sharply defined communities of *Calluna vulgaris* on the Wiltshire Downs, the tendency of the plant to spread being apparently determined by definite factors

As a preliminary step, the vegetation was mapped and a series of soil analyses made of the soils inside and outside a *Calluna* area Experimental work was undertaken with the object of throwing light on the soil preferences of *Calluna*, and possibly on the edaphic relations of 'calcifuge' plants in general

Experimental Results

In water cultures *Calluna* seedlings grow equally well in neutral or faintly acid solutions, but are very sensitive to changes in the concentration of the culture fluids

Artificial cultures have, up to the present, lent no support to the view that the $\frac{MgO}{CaO}$ ratio has any significance, as was suggested by the soil analyses

In pot cultures, using soil from the chalk down immediately outside the heather area, germination capacity is lowered and rate of germination much retarded as compared with what occurs when soil is used from within the area

Growth is inhibited in seedlings grown in the former soil, root growth is checked and the tips of the roots show curvatures Bacterial colonies, especially associated with the root-tip, and often forming a sheath round it, are a prominent feature of such roots in quite young seedlings Partial sterilisation of the unfavourable soil does not affect this result

In sterile agar cultures, using soil extracts from the same two soils, untreated or imperfectly sterilised seeds show a zone of growth due to micro-organisms associated with the seed coats The character of these growths differs markedly in the two sets of plates In the extract from heather soil they are chiefly composed of mycelium, in that from chalk-down soil bacterial cultures are the most prominent feature

Using data so obtained, the problem may be stated as follows Are the soil preferences and peculiarities of *Calluna* specific to the plant, or are they indirectly affected by the association of a mycorhizal fungus with the roots, the growth of which, in its turn, is determined by the nature of the soil and its bacterial flora

The following points require elucidation before the main problem can be attacked —

1 At what stage and from what sources does infection of the root take place?
2 Is it possible (*a*) to germinate, (*b*) to grow *Calluna* without infection under sterile conditions?
3 Can it be shown that definite races of bacteria are associated with the roots, which, given certain conditions, become directly or indirectly pathogenic to the plant, or are the appearances observed of a secondary nature?

Investigation of these points is in progress, and has, up to the present, yielded the following results —

Seedling roots, whether germinated in soil or not, are infected, soon after germination, with a mycorhizal fungus

This infection commonly takes place by a growth of hyphæ from the seed coat, which grow across and infect the root of the young seedling

Seeds can be successfully sterilised by immersion in 1 per cent solution of corrosive sublimate for one to two minutes and germinated in a perfectly sterile condition on agar plates

Germination under such conditions takes place normally and the seedlings start growth in the usual way

Such sterile seedlings are being grown under sterile conditions in sand and in agar nutrient media

Some work has been done on the cultivation of the mycorhizal fungus and on the isolation of bacteria constantly associated with the roots under unfavourable conditions

5 *A New Jurassic Member of the* Marattiaceæ
By H Hamshaw Thomas, *M A*

Among the recent additions to the Jurassic flora of Yorkshire is a fern which I have called *Marattiopsis anglica* It is characterised by the possession of pinnæ which are sometimes 30 cm long, each with a stout mid rib and secondary veins which dichotomise only very near their origin The fertile fronds are similar in form to the sterile, but bear large synangia on their veins, these usually occupy most of the space between the midrib and the margin In some cases the remains of the young unopened synangia with rounded ends are seen, but in other specimens dehiscence had taken place before preservation, and the two halves are apparent, one on either side of the vein, and each showing a considerable number of loculi The synangia were evidently of a stout texture, and had an outer layer composed of rounded cuticularised cells The spores were small (30 μ in diameter), and had a roughed appearance due to the presence of numerous small projections, they do not exhibit clearly a tetrahedral scar, but sometimes appear to possess a simple scar These spores are almost identical in size with those of the modern Angiopteris In all the points of structure which we are able to observe, *Marattiopsis anglica* closely resembles a recent Marattia It is closely allied to the Rhætic *Marattiopsis Munsteri*, which was indeed placed by Schimper in the modern genus

The evidence from this Yorkshire form makes it clear that a group of ferns existed in the Mesozoic period which were very similar to the modern Marattias Other forms have been found in various localities which can be assigned with some confidence to the Marattiales, especially Nathorstia and Danæites On the other hand some of the fronds which were thought to be sterile specimens of Marattiaceous affinities are probably the remains of Bennettitalean fronds In the case of the well-known *Tæniopteris vittata* from Yorkshire, the epidermal structure points to its inclusion among the Bennettitales

The presence of Marattiaceous ferns in the Carboniferous period is well established, and it is increasingly probable that some of the modern types were differentiated at an early period in the Mesozoic, and must be regarded as the most ancient of our ferns

6 *On the Structure and Affinities of a New Specimen of* Sutcliffia
By E de Fraine, *D Sc*

This fossil stem is attributed to the genus *Sutcliffia* on account of the close correspondence in general structure and histological details It is provisionally regarded as representing an older stage of a small specimen of *Sutcliffia insignis* (Scott) A wide, irregular zone of secondary cortex lies immediately beyond the 'pericycle,' and limits the fossil, all the outer tissues having been exfoliated

The stele and 'meristeles' are surrounded by a great thickness of secondary tissue

The vascular system is further complicated by the presence of anastomosing

strands of secondary wood and bast, which formed a network round the steles and 'meristeles.' These strands strongly recall those of certain genera of Cycads, both as regards their irregular arrangement and occasional inverse orientation, and in their minute structure. An accessory vascular strand, similar to those of *Medullosa anglica* and comparable with the cortical bundles of *Cycas,* is also present.

The stem is regarded as possessing a protostele, from which large leaf-trace strands ('meristeles') were given off; these latter were ultimately entirely used up in the production of concentric foliar bundles of either the radially symmetric or unilateral type. The vascular structure is thus brought into closer relation with *Medullosa anglica*.

The fossil is considered to be of some importance on account of its possible affinities with the Cycads, and the suggestion is put forward that it is from such a monostelic type as *Sutcliffia*, rather than from the polystelic members of the Medulloseæ that the origin of the Cycadaceæ is to be sought.

MONDAY, SEPTEMBER 9.

The following Papers were read:—

1. *Some Impressions of the Flora of Northern South America.*
By Professor D. H. CAMPBELL, *Ph.D.*

2. *The Root-nodules of the Podocarpeæ.*
By Professor W. B. BOTTOMLEY, *M.A.*

Noble and Hiltner in 1899 demonstrated that the root nodules of *Podocarpus* were concerned with the assimilation of nitrogen. Shibata in 1902 attributed the formation of the nodules to an endophytic mycorhizal fungus. Bottomley in 1906 showed that the root-nodules of *Podocarpus chilina* contained nitrogen-fixing bacteria similar to those found in the nodules of leguminous plants.

Root-nodules are found in all the genera of the Podocarpeæ, viz., *Podocarpus, Dacrydium, Microcachrys, Saxegothaea,* and *Phyllocladus*, and their structure has recently been investigated by Miss Spratt, of King's College, London.

The nodules are always arranged in two distinct rows along the sides of the roots, and are evidently modified lateral roots, being developed from the pericycle cells opposite the protoxylems of the diarch root. Infection and subsequent arrest of normal development of the lateral root is caused by the entrance of bacteria into the cortical cells through the root hairs in the first instance.

The mature nodule consists of a central stele which is continuous with that of the root, surrounded by a cortical mass of parenchymatous cells containing bacteria, and an outer layer of cells which often produces root-hairs.

The bacterial tissue of the nodule remains active for one season only. Towards the end of the season most of the cells lose their contents and their walls become thickened by the formation of characteristic bars of cellulose. The following spring a new mass of active bacterial tissue is formed by the activity of the pericycle cells of the stele, and the old cortical cells with their barred cell-walls are squeezed out to form an outer protective zone. Although several 'annual' zones may be seen in a nodule, the original outermost layer of cells of the nodule remains intact, except in the bifurcated nodules of *Saxegothaea*.

This formation of fresh bacterial tissue each year is characteristic of all root-nodules, both leguminous and non-leguminous, concerned with the assimilation of atmospheric nitrogen.

All the nodules of the Podocarpeæ are simple structures, with the exception of *Saxegothaea,* which has bifurcated nodules.

The presence of root-nodules in *Phyllocladus* supports the contention of Young that it must be regarded as a member of the group Podocarpeæ rather than of the Taxeæ.

3 *Some Effects of Humates on Plant Growth*
By Professor W B BOTTOMLEY, *M A*

Peat-moss litter is said to be 'entirely unsuited for the growth of plants' It is acid in reaction and contains no soluble humates

It has been found, however, that when peat is treated with certain micro-organisms a large quantity of soluble humate is obtained and the peat is rendered alkaline An aqueous extract of this treated peat (one part peat to 200 parts water) will supply all the plant-food necessary for successful water-culture experiments As no trace of nitrate was found in the culture solutions during the whole course of the experiments, it is evident that the nitrogen-need of the plants was supplied by some form of organic nitrogen present in the solution.

Water-cultures with tomato seedlings, germinated in sterilised sand, showed that the plants failed to grow in raw peat-extract, but in treated peat-extract the plants grew well, flowered, and produced fruit Experiments with buck wheat, radish, and barley gave similar results

---

4 *On some Morphological Varieties of* Cladothrix dichotoma (Cohn)
By Professor DAVID ELLIS

Cladothrix dichotoma is one of the thread-bacteria, and is widely distributed throughout Europe Its economic importance is considerable, because its presence in iron-waters is associated with the accumulation of the red ferric hydroxide, thus causing a considerable impediment to the flow of water through pipes The present investigation has brought to light the following —

1 There are morphological as well as physiological varieties of this organism The normal or central variety has sub-polar cilia The variety under investigation possessed polar cilia Sphærotilus natans is probably another variety of *Cladothrix dichotoma*

2 Under certain conditions, multiplication is effected by the slipping off, sideways, from the parent thread, of small portions, which immediately assume a *spiral* form, develop polar cilia, and, except in the stained condition, are indistinguishable from members of the *Spirillum* group When stained, however, these spirilla are seen to be composed of typical rod-cells, enclosed in a common sheath The existence of these 'spirilla' was asserted by Zopf in 1882, but has since been denied by subsequent writers

3 The sheath enclosing the rods is composed at first of a thin mucilaginous covering, closely investing the rods The sheath subsequently hardens By appropriate treatment it can be shown that the sheath has transverse septa, dividing it into compartments, and that each compartment contains a single rod-cell

4 Each rod cell has a well-defined membrane, and in the cytoplasm, besides the oil-drops which had previously been found, reserve material in the form of *glycogen* was identified The cell-membrane seems to serve, in addition to the cytoplasm, as a storehouse of food material, as when the organism is cultivated artificially, and the threads stained with iodine, the membrane takes up the characteristic sherry-brown colour of glycogen Further, as the reserve material became used up, the sherry-brown colour gradually disappeared till the membrane ultimately appeared quite colourless when treated with iodine

5 Multiplication takes place in the case of attached threads by the liberation of motile or non-motile cells from the opening at the apex, by the slipping out sideways of individual cells, or by the growth and multiplication of detached fragments In the case of motile threads, multiplication takes place, so far as could be observed, only by the detachment of fragments, which on liberation assume motility, and then grow and divide to form mature threads

6 The division of the rod-cells takes place in precisely the same manner as cells belonging to the bacillus group

7 *Cladothrix dichotoma* shows affinities to the bacillus and spirillum groups and to the Cyanophyceæ, but is very far removed from the streptococcus group with which it has often been confounded

Reduction Divisions (?) in Somatic Tissue. *By* R R Gates, *M A , Ph D*

In connection with a study of somatic mitoses in the nucellus of *Oenothera lata* certain peculiar phenomena were observed in rare cases, indicating that a reduction division was about to take place

Regarding normal somatic mitosis the following points may be mentioned —

(1) The number of chromosomes in the individual studied was 15, and it is not improbable that the extra chromosome is constantly associated with the *O lata* characters

(2) The resting nucleus contains a uniform reticulum, with no indication whatever of bodies corresponding to prochromosomes

(3) The chromosomes are variously arranged when they arise from the reticulum, but they are not evidently paired, nor do they form a continuous spireme at any time

(4) Later in the prophase, and particularly in a polar view of the metaphase, they are often clearly in pairs side by side

(5) A conspicuous longitudinal split appears in the chromosomes in prophase, but afterwards closes up Certain variations in chromosome number are ascribed to the precocious separation of the daughter chromosomes formed by this split

(6) In telophase the chromosomes pass through a transient stage in which they show a transverse median constriction, but there is no indication of any split before they pass into the resting condition

The chromosomes in certain cells were found to differ from their normal rod-like shape

Two nucellus cells were observed in which the spindle was much larger than usual, one spindle being as long as the heterotypic spindle in the megaspore mother-cell The chromosomes on this spindle were several of them joined laterally to form close pairs or bivalents, the members of certain pairs being partly fused The chromosomes were also oriented differently from their usual position on the spindle

The relatively great size of this spindle, together with the various peculiarities of the chromosomes, makes it probable that a somatic reduction division was about to take place

---

6 *The Values of different Degrees of Centrifugal Force on Geotropic Stimuli* *By* W E Hiley, *M A*

The method of obtaining these values is based on the same principle as Fitting's intermittent clinostat

Seedlings are pinned to the back of the inside of a box which, when still, remains in a vertical position The box is attached to a rod which can be made to revolve about its middle point, at about two hundred revolutions per minute, in a horizontal plane When the rod is rotating the box automatically takes up a position so that the back lies in the line of the resultant of the centrifugal force and gravity, and in such a way that the centrifugal force would stimulate a bend in the radicles in the opposite direction to that stimulated by gravity when the box is at rest

The centrifugal 'wheel' is driven by an electric motor By means of a clock whose arm dips into mercury through part of its course, the electric current driving the motor is made to pass only for regulated periods—say, one minute in every ten

Thus the seedlings in the box are subjected alternately to the stimulus of gravity in one direction and any prearranged centrifugal force up to $20g$ in the opposite direction

A successful experiment is one in which these two opposing stimuli neutralise each other, and the radicles of the seedlings show no ultimate bend in either direction, and it is then found that if C be taken as the centrifugal force which alternates with g (gravity), and if C be allowed to work for a period T, and g for a period t, then $CT=gt$, or, in other words, that the stimulating force (acceleration) multiplied by the time of action is the same in each direction

These results, however, were only obtained when the times were short (? not greater than the *presentation time*) If the summation of the individual times in the two directions (T and t) is greater than about fifteen minutes, it is found that the larger force has less effect than would be calculated from the above equation, and the radicles must be exposed to the force for a longer time in proportion to the period at rest, *i e*, $CT > gt$ when a result without any ultimate bend is obtained

Most of the work has been carried on with the radicles of *Helianthus annuus* and *Cucurbita Pepo* about ½ to 1½ cm long

7 *Thermotoxy, or Factors in the Growth of Cotton in Egypt* *By* W LAWRENCE BALLS

Investigations of the growth of a fungus-hypha, with temperature as the limiting factor,[1] showed that growth accelerated according to chemical laws with rise of temperature up to 37½° C, when it was rapidly arrested The position of the so-called optimum was determined by the rate of heating This arrest was due to the formation and excretion of a toxic katabolite, and the 'stopping-temperature' could be fixed at any desired point from 15° C to 37½° C by using various concentrations of this stale culture-medium mixed with fresh medium or with water The excretion accelerated more rapidly than the growth-rate as the temperature rose, and so neutralised it The toxin itself was not isolated pure, but it could be decomposed *in vitro*, or removed from stale cells by washing or by desiccation and storage

Similar interpretations are indicated by the higher plants In their case the removal must be due to decomposition—probably oxidation The effect is clearly shown by Egyptian cotton under field conditions, since the growth takes place chiefly during the night, the water-strain brought about by high sun-temperature and low humidity preventing growth in sunshine during a great part of the growing season Growth therefore follows the night-temperature as a rule, but when the day-temperature has exceeded 35° C we find the growth during the following night to be subnormal, limited by the accumulated toxin If a normal day follows, the toxin is decomposed and the next night's growth is normal

Continued repetition of such over-heating results in complete arrest of growth in the affected bud Different races and species of *Gossypium* differ in their liability to this poisoning under the same conditions, without any relation to their temperature-acceleration of growth Hybrids therefore show most various growth-relationships in F2, *e g*, slow but continuous, rapid but discontinuous, &c, and there are indications that a Mendelian segregation may be found

Such over-heating may be caused if the plant is short of water, although the shade air-temperature does not exceed 35° C, since closure of the stomata results in partial loss of thermo-regulation, and in a rise of tissue-temperature above air temperature even to 10° C Simple water shortage needs to be differentiated carefully from the heat-poisoning which it may entail in hot climates The effect of root-asphyxiation by a rise of the water-table acts partly in this way

The growth-temperature curve of the root in non-aerated water-culture suggests a similar toxic accumulation as the result of a limited air-supply The general conception of toxic katabolites accumulating too rapidly, or being too slowly decomposed, seems to be useful, direct chemical investigation should be feasible, as in the analogous case of muscular fatigue

There is a hint of a wider generalisation in the hypothesis of Thermotoxy—namely, the possibility of antagonising this effect by an antitoxin, both in plants and in animals White men in the tropics are exposed to supernormal temperatures for long periods, and the intermittent breakdown of their thermo-regulation is shown by the greater frequency of low fevers and slight rises in temperature due to extraneous causes, as compared with the same in Europe An anti-thermic serum, were it possible, supplementing present precautions against sunstroke, malaria, and so forth, would enable the white races not merely to occupy, but to colonise the Tropics

[1] *Ann Bot*, 1908

8 *Plant Breeding at St Andrews* *By* Dr J. H WILSON.

9 *The Botany of the Abor Expedition A Study of the Forests of the Abor Hills, Eastern Himalaya.* *By* I H BURKILL, *M A*

The author had the fortune in 1911 to be named by the Government of India botanist to the Abor Expedition Leaving Calcutta in November, he joined the force at Kobo, in the plain of Upper Assam, and proceeded into the hills of the Abors, where nearly four months were spent in exploring the dense forests near the Dehong River up to 6,200 feet

Forest is the natural clothing of the Abor hills, where it obliterates the clearings of man quickly, and where woody plants, following herbs, invade the less inviting spots (1) as epiphytes securing places in the tree-tops, (2) slowly spreading on to the rivers' sterile sandbanks, and (3) invading the river-beds between their June level and their January level The author used his time chiefly in studying the constitution of the different types of forest met with, and these three intrusions

The Plains forest is in a way a northward extension of the vast forests of Malaya Like all tropical rain-forests, it has a great variety of foliage It has three layers—(1) the layer of the wind-dispersed, relatively small leaved, giant trees, (2) the layer of the animal-dispersed, large-leaved, lesser trees not growing beyond the still air, and (3) the layer of the ground vegetation wherein the plants are not large-leaved except in the alleyways of the forest The second and third layers are separated by a light-diffusion space

In their relation to creepers the trees of the forest differ in interesting ways some thrive by outgrowing the creepers in annual spurts, some thrive by smothering them

The Lower Hill forest is of two kinds On the south slopes it is not unlike the Plains forest, but on the north slopes rules a most distinct and characteristic forest composed chiefly of a tree called by the Abors 'Shingkeng' There is little variety in the foliage of a Shingkeng forest Above the base of the hills oaks appear, and rule in places On very steep slopes a giant bamboo rules The Upper Hill forest has very uniform foliage, and is rather of two layers than three

Grasses, as in the Sikkim forests, are very rare in the whole countryside, it is only where the very copious rain is drained away to an unusual extent that they can exist thus, the very steep slopes harbour the giant bamboos, Abor clearings on hill crests enable *Saccharum* to exist for a while, very well trodden paths in the immediate vicinity of villages allow two species to grow, sandbanks grow grasses, one invades the river-bed, clinging to rocks, and the gravel beds at the foot of the hills after cultivation become covered with *Phragmites*

Elsewhere grasses, even on clearings returning to jungle, do not exist The clearings after the crop is removed are seized on by *Ageratum*, *Bidens*, *Blumea Gnaphalium*, *Triumfetta*, *Viola*, &c Then follow shrubs out of which a *Calophyllum* and a *Macaranga* gradually come to rule, the foliage getting larger as the height of the scrub increases, until finally it passes back to the true forest

The river's clearings are sandbanks Grass, first of all, takes possession of them, then slowly trees invade them, those which come first being the most deciduous species of the countryside

The fall of the River Dehong in the hills is 50 to 60 feet Of terrestrial plants, a moss ventures furthest into the exposed river-bed, not quite so far ventures a *Jungermannia*, a fern, an *Equisetum*, a *Polygonum*, and the curious Euphorbiaceous *Homonoia* descend to a limit which has a longer period above the flood, another *Equisetum*, two other ferns, and *Rhabdia* of the Boraginaceæ descend half-way, the grass already mentioned, a *Lactuca*, a *Blumea* (Compositæ), *Viola Patrinii*, a *Ficus*, and some other plants occupy in increasing degree the upper part of the banks The grass makes such a dense mat of roots as to resist the wash of the current and to hold a soil The *Homonoia* is a tree with a trunk buried in the shingle

Humid all the year round, it is only on the blufts and south slopes of the Abor hills that trees bare after their leaf-fall for more than a month are found Where bare trees stand, the epiphytes of the upper layers of the forest can be

seen easily, they are more commonly in considerable aerial gardens than solitary, for the presence of one plant enables another to get a footing. As with the forest trees, the larger leaved epiphytes are rarely in the topmost layers of the forest, but live a little below.

Mosses and film-ferns are abundant on the tree-trunks, neither store water, but both withstand desiccation. Two film-ferns were sent alive to Kew in a letter—a matter of a month in post-bags—without any protection against desiccation, and are now growing there.

Epiphytic figs are common in the forest, where the crown of one attains a greater span than other trees, and its roots find their way to the soil more than one hundred feet below.

The forest attains a height of 120 to 180 feet. Phanerogamic parasites are common in it, showy mistletoes living in the tree-tops, and leafless parasites being common on the ground, such as the coral-red *Balanophora dioica* and brown *Rhopalocnemis phalloides* (Balanophoraceæ) and dark blood-red *Sapria bengalensis* (Cytinaceæ), which live on the giant vines, where these, running through the tree-tops, make the light on the ground below too dim for foliage plants.

The lecturer measured the light in several places, finding it reduced to $\frac{1}{200}$ to $\frac{1}{300}$ and even to $\frac{1}{410}$ of full sunlight.

As far as known to the author, from the observations of Major Sweet and Lieutenant Oakes, coniferous forest commences at 9 000 feet in the hills beyond those which he was able to visit.

TUESDAY, SEPTEMBER 10

Joint Discussion with Section D on the Origin of Life.—See p. 510.

The following Papers were then read:—

1. *Vitality and Distribution of Growth in Defoliated Larch Trees.* *By* Alan G. Harper, *B.A.*

Trees partially or completely defoliated, in two or more successive seasons by the larvæ of the large larch saw-fly (*Nematus erichsonii*).

General effects of the defoliation: (*a*) reduction in radial growth increment; (*b*) reduction in the ratio of autumn tracheides to the total breadth of the annual ring.

In extreme cases the radial growth increment ceases entirely, or the cambium is active over parts only of the circumference, so that a partial ring results. The autumn tracheides may have their walls no more thickened than those of the spring wood, but are smaller in size. Or the earliest formed tracheides may be normal, but those formed at the close of the growing period are again thin-walled, the food supply having run short.

Both these effects, reduced growth and reduced percentage of autumn wood, are greatest at the base of the trunk and steadily decrease as one proceeds upwards.

Three examples:—

A. Forester's report on tree at time of felling, *Flourishing*.—A radial growth increment has been found every year since before the beginning of the attack, both at base and at the top and in all parts of the trunk. For one year the autumn tracheides remained totally unthickened, but there has been a recovery during the last two years, both in size of the increment and in percentage of autumn wood, and this recovery is much more marked in the upper part of the tree.

C. Forester's report, *Dying*.—As in B, growth at the base had ceased two felling, but the upper parts still continued to grow in thickness, and at the tip of the tree there was a slight recovery of the autumn wood percentage in the last year before felling.

C. Forester's report, *Dying*.—As in B, growth at the base had ceased two

years before felling, but the last year showed at the tip an increase in the radial increment and in the autumn wood percentage, suggesting a partial recovery

Other points noted in the research —

1 Pathological formation of zones of contiguous resin ducts, especially at the boundary between two annual rings

2 Partial rings may be produced, even over very small areas of the meristematic sheath, when the cambium is failing in activity Also the size of the radial increment may differ greatly even along two very closely adjoining radii

3 The hardness of the timber seems to be independent of the percentage of autumn wood in the annual rings [1]

2 *The Geological Evidence with regard to the Relative Age of the* Abietineæ *and the* Araucarineæ *By* R B Thomson, *B A.*

Two forms have been considered important as indicating the great age of the Abietineæ, *Pityoxylon chasense* of the Permian and *P conwentzianum* of the Carboniferous Both these forms have recently been shown not to be authentic—the former structurally and the latter geologically There is left no Abietinean form either in or earlier than the Triassic, where the first Araucarian (Woodworthia), according to the theory which regards the Araucarineæ as derived from the Abietineæ, makes its appearance The conclusion is sufficiently evident, but certain features of the forms which are considered transitional to the Araucarineæ are pertinent The Triassic form, Woodworthia, has only the spur shoot of the Abietineæ, being in pitting and ray structure practically Cordaitean or Araucarian This spur shoot, too, is of a very primitive type—persistent and with many leaves Araucariopitys of the Cretaceous closely resembles a pine—in pitting, in ray structure, in resin canals and in its early deciduous spur shoots That the older form should show more Araucarian features and the more recent one have the more pine-like structure is the reverse of what the Abietinean theory of the ancestry of the Araucarineæ demands The evidence from these transitional forms geologically considered is in accord with and supplements that of the geological records themselves

3 *The Zoospores of the* Laminariaceæ *and their Germination* *By* J Lloyd Williams

In consequence of the announcement by Drew that the so called zoospores of Laminaria are gametes and that he had observed their fusion, the author repeated the investigation described by him at the Bradford meeting of the British Association, employing, in addition to other methods the culture solution method used by Drew The conclusions originally arrived at were confirmed As might have been inferred from Drew's own description and figures, the colourless, spherical, fusing organisms seen by him were not the Laminarian zoospores, but monads The real pear-shaped zoospores, with their prominent bent chromoplasts, never fuse When they settle down they become spherical, are invested with a wall, and the curved chromoplast divides in two at the bend A long tube grows out at one side of the spherical spore case, into this the two chloroplasts and most of the other contents migrate, the nucleus remaining behind The nucleus now divides, and the two daughter nuclei move into the tube An enlargement is formed at the distal end, in which are found one of the nuclei, the chloroplasts, and most of the other cell contents A transverse wall separates it from the tube, in which the second nucleus, together with a trace of cytoplasm, may be found, later on this nucleus degenerates and becomes a structureless mass

The new cell grows in size, the chloroplasts multiply, and division may take place, in which case a single chain of cells or an extensively branched, protonematoid structure may be formed The protonema may give rise to a Laminarian germling in a fortnight or less, or it may remain in this condition for many months

[1] Cp Hartig, *Holzuntersuchungen*, S 6, Berlin, 1901

The process of germination is very curious A cell of the chain becomes pear-shaped The wall at the pointed end becomes exceedingly thick, and appropriate stains show that the swollen part is very mucilaginous The pressure in the cell forces many of the chloroplasts together into the narrow end, the thick wall bursts, the contents emerge, enclosed in a thin pellicle, the original cell being left empty but with the aperture at the end obliterated The newly emerged cell, oval in form, divides and forms a row of cells, and the basal cell puts out one or more rhizoids, which often grow along the outer surface of the empty cell wall Drew has figured the germlings with their rhizoids inserted in the empty cell, as if the young plant had been completely formed inside the protonematoid cell

The genera examined were *Laminaria* (*digitata* and *saccharina*), *Alaria*, and *Chorda* In all the forms the process was the same, and there can be no room for doubt that the well known swarming bodies are asexual

---

4 *The Reproductive Organs of* Fitzroya patagonica (*Hooker fils*) *By* R C McLean, *B Sc*

Fitzroya patagonica, the 'Alerze' of South America, is a somewhat peculiar member of the Cupressineæ (Actinostrobineæ), which grows in Southern Chile and Patagonia It is confined to marshy ground, and forms large groves, some individuals attaining even 180 feet in height

In England it does not reach large dimensions, but nevertheless flowers with freedom The flowers have never been properly described Usually the tree is diœcious, but some few specimens are known to be monœcious These latter often bear bisporangiate cones All the flowers are borne on short lateral branches, axillary to leaves of the main shoots

The *female flower* consists of a cone about 5 mm in length, formed by three alternating, trimerous whorls of scales, increasing in size from the base upwards, and borne upon an axis with internodes suppressed The lowest whorl is small and normally sterile, the second whorl varies from complete sterility to bearing a single ovule on each scale, but the upper whorl, composed of large, very fleshy, divaricating scales, is much the most important

The ovules are sessile upon the upper surface of the scale, and vary greatly in number Scales of the second whorl never bear more than one, scales of the upper whorl may have one to six The form of the ovules is peculiar, the body is fusiform, 2- or 3-winged, and the single integument is prolonged upwards so as to form a micropylar tube, expanding terminally into a stigma In the centre of the flower are three clavate glands which secrete an aromatic resin These glands may represent a metamorphosed whorl of scales

The *male flower* forms a slender, cylindrical cone, 1 cm in length, consisting of six alternating, trimerous whorls of thin, pointed scales, attached to the cone axis by peduncles Four ovate sporangia are attached to each peduncle The apical whorl is sometimes entirely concrescent

The *bisporangiate cones* have an increased number of whorls Three sterile whorls at the base, then three whorls bearing microsporangia, and, uppermost, the two female whorls, with a reduced number of ovules

5 *Vestigial Floras* *By* A R Horwood

In making an ecological survey of East Leicestershire certain remnants of a rich former flora contrasting with the uniform, and otherwise dissimilar, mesophytic flora (of which the tract is largely made up), have been discovered, for which the name *vestigial floras* seems appropriate

Had the area been anything but a very commonplace, ox pasture region, studded with modern woods and artificial pieces of water, these features would not have required any distinctive term, but the clearness with which they stand out from the barrenness of this region warrants some graphic mode of expressing the contrast, and indicating the genetic phase they represent

Indications of old bogs and heaths have been found as the survey progressed, which in this vestigial form have not been noticed so far

Thus on Middle Lias (*margaritatus shales*), near Cold Newton *Eriophorum*

angustifolium, Orchis incarnata, Carex stellulata, Carex ovalis were found in an ordinary pond, along with common wet-meadow species. The first had never been found in East Leicestershire, and the third is chiefly restricted to the Charnwood district. This is a *vestige* of an earlier bog, doubtless extensive, when, before the enclosure, the whole tract was woodland. Similar bogs are indicated by small swampy tracts, a yard or so in area, with *Œnanthe Lachenalii* and bog mosses in two spots, and *Scirpus compressus, Orchis incarnata,* and other bog-mosses at King's Norton. Here again these vestiges were completely surrounded by mesophytic vegetation.

Heaths, too, are still indicated by similar vestiges. Near the *Eriophorum* bog is a tract covered with clumps of *Nardus stricta,* also practically unknown in East Leicestershire, associated with *Pedicularis sylvatica* (very rare here) and ericetal lichens, in addition to common ericetal phanerogams. Again, near the last spot, *Galium saxatile, Polygonum hydropiper,* and other ericetal species, *e.g., Sieglingia* cropped up, as a further example. Some other heaths nearer Leicester, to-day closely grazed, are represented by *Thymus, Stellaria graminea, Festuca,* but particularly by ericetal mosses. These last survive after *Ulex* and all the typical common and heath plants have disappeared.

Two points are thus clearly established. Firstly, amongst mesophytic plant-formations the existence of other and once prevalent natural formations can be detected by the presence of vestigial elements, by aid of which it can be possible to reconstruct the true original type of vegetation.

Secondly, the paucity of phanerogamic plants afforded by these vestiges, though sufficient perhaps in themselves to establish the type of vegetation, may be satisfactorily balanced by the usually accompanying cryptogamic flora, which is often abundant and survives where phanerogams have become extinct.

SECTION L.—EDUCATIONAL SCIENCE.

PRESIDENT OF THE SECTION.—PROFESSOR JOHN ADAMS, M.A.

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

An Objective Standard in Education.

OF those who deny to Education a place among the sciences the name is legion, for they are many. The mere classification as a science is not perhaps of much consequence, but it is useful for the student of Education to examine the popular view, and see how far it is justified. The following statement, the words of a former occupant of this chair, will be generally accepted as representing the prevailing opinion:—

'If we take science to mean, as commonly understood, organised knowledge, and if we are to test the claim of any body of facts and principles to be regarded as Science by the ability to predict, which the knowledge of these facts and principles confers, can we say that there exists an organised and orderly arrangement of educational truth, or that we can logically, by any causative sequence, connect training and character either in the individual or in the nation? It is very doubtful whether we can say that educational science is yet sufficiently advanced to satisfy these tests.'

First with regard to organised knowledge, there is certainly a great mass of matter available in the subject of Education. It is true that there is nothing easier than to show that this matter is not at present well organised. It is only too easy to find examples of contradictions among those who make a study of Education and venture to write or speak on the subject. We are told that there is hardly any important statement made by a writer on Education that cannot be met by a direct contradiction in the works of some other educational writer. It has to be admitted that writers on Education in the past have been strangely opinionative and dogmatic in view of the very complex and delicate problems they have had to handle. Too frequently they assumed a simplicity in their subject-matter that was certainly not there. Even the massive common sense of Dr. Johnson was not able to keep him from regarding Education as a study that had reached its limits long before his time. But between those who regard Education as too simple to need any further examination, and those who treat it as so complex as to defy human analysis, there are those who take the view that Education is a science like any other, though they admit that there may be room for wide difference of opinion regarding the stage of development it has reached.

At the present moment it is becoming increasingly evident that educational theory is consolidating: it can now be claimed that there exists a great body of educational doctrine that is of general acceptation. It goes without saying that there are many and deep differences among the various schools of educational writers. But if we compare any two schools we shall find that the points of agreement far outnumber the points of difference. This was true even in the

older times of naïf theory, but is making itself very evident in these latter days. Anyone who has occasion to read all the books on the theory of Education as they appear, is impressed in spite of himself by the large body of doctrine that is common to them all. It is not that the books lack originality: each writer has his new point of view or his new interpretation of certain phenomena; yet each either baldly states or tacitly takes for granted a great body of truth that is held to be generally accepted. This body of recognised truth is gradually increasing as the result of collective thinking and the corrections involved in active criticism. Already critics are beginning to find fault with any writer who produces a book—not avowedly a text-book—that professes to deal with the whole range of Education. He is reminded that what is now wanted is a special development along certain definite lines. The general principles of Education are held to be established and accepted.

In confirmation of what has been said, it may be added that within the past year or two have appeared no fewer than five separate treatises each bearing the same title 'The Principles of Education.' These books are mainly for the use of students, and contain what are regarded as the accepted results of educational investigation up to the present date. Their authors obviously recognise the existence of a certain body of truths on which all are agreed. In some of the professions it is customary to speak familiarly of 'the books,' meaning the standard works to which appeal is constantly being made. If among teachers we have not yet reached this stage, we are obviously far on the way towards it. The books are there, but the profession needs some time yet before, in its own deliberate way, it recognises their importance. By and by it will realise the fact that it has at its disposal material that will enable it to prophesy and thus fulfil the second condition imposed upon all who lay claim to scientific knowledge. It is true that in the past there was little diffidence about prophesying: it was the fulfilment that gave trouble. Wolfgang Ratke supplies if not the first at any rate the most dramatic application of a control test in the working of educational prophecy. He went to prison because the people of his time did not make allowance for the insufficiency of the body of knowledge on which he based his predictions. There was indeed nothing scientific about the procedure of Ratke. He was at the empirical stage, and could not rise above it. His modern fellows have not quite got beyond the empirical, but they are on their way.

No claim is here made that Education has yet justified her demand to be recognised as a fully developed science, but it may be fairly maintained that she has at least entered upon the stage of scientific method: she is seeking to free herself from mere empiricism. In such a struggle there are at least two possible lines of action.

The first requires some ingenuity, but is natural and pleasant. It consists in superimposing principles upon the facts of the case. The educational theorist invents or assumes certain broad general principles, then proceeds to fit in all the observed facts, and often shows great skill in the process. This method is of very general application. Sometimes it is worked consciously and deliberately, as in the case of Socrates' doctrine of Reminiscence. Here we have the whole scheme of teaching simplified by this superimposed generalisation. Quite frequently, however, the broad underlying principles are not brought to clear consciousness, and are, in fact, sometimes contradictory to each other. Examples may be found in Rousseau. For our present purpose this tendency towards what may be called rational pedagogy is best illustrated in the system of Education elaborated by Herbart. Though the metaphysical basis on which he builds is generally regarded as false, it was deliberately adopted by him, and if it is once granted to him all the rest of his system must be admitted to be built up on strictly scientific principles. It is true that while logically Herbart's pedagogy was built upon his psychology, in point of fact his pedagogical thinking preceded and dominated his psychological theory. While Pestalozzi sought to psychologise Education, Herbart may be said rather to have educationalised psychology. In any case he supplies us with a system that challenges recognition as scientific, whether the claim be admitted or not.

The other method by which a study may seek to escape from mere empiricism is by dealing with observed results so as to reach the underlying principles. In this method, instead of setting up principles and making the facts square with them, we examine the phenomena and seek to discover the underlying principles.

Obviously this at once introduces the experimental method, since no satisfactory progress can be made by mere passive observation. This is the stage we have now reached in educational theory. We are passing from an appeal to experience to an appeal to experiment. Naturally educational method has always had to stand or fall by its results, but in estimating results there has too frequently been a confusion between cause and effect. So soon as a conscientious analysis of educational problems is attempted there comes the need of experiment. Certain questions have arisen demanding a definite answer, and the answers supplied must stand the test of practical application. Education is, in fact, called upon to prophesy, and to stand or fall by the results. Now the method of experiment is really a system of tentative prophecy, under rigidly determined conditions. We acquire skill in prophesying by a process of trial and error. We become prophets by prophesying. From all the knowledge at our disposal we calculate that a certain process will give a certain result. We apply the process, and then if the result is not what we expected we examine all the conditions, seek out the cause of our error, and proceed to another tentative prophecy. By and by we acquire the power of prophesying with confidence within certain recognised limits, and within those limits we may claim to proceed scientifically.

But in the evaluating of results that is necessary in this process of training in prophecy there is need for some recognised standard. Unless this condition be fulfilled there can be no general agreement among investigators. Accordingly the first step in raising a study to the scientific level is the establishment of such a standard. In the study of Education in the past—and it must be admitted that the same is true to a large extent at the present—the standard adopted was in most cases a subjective one. There is a tendency to have everything determined by individual opinion. Certain educational processes are gone through, certain results follow in the lives of the educands. The causal relations involved are arranged by the individual observer to suit his own views. According to some the battle of Waterloo was won on the playing-fields of Eton, according to others the battle of Colenso was lost there. We have need of some standard that is independent of private opinion.

Obviously the whole question of the relativity of knowledge is here involved. The educator is too apt to apply to his own case the Protagorean view, and maintain that 'man is the measure of all things, of things that are, that they are, and of things that are not, that they are not.' Into this antique problem we need not here enter. There is a sense in which the epigram of Protagoras may be justified. Without doubt, for his own practical purposes, the individual is the measure of his universe of experience. But so far as his universe has to do with the universes of others, the individual needs some common standard, something outside of himself, something that others besides himself recognise—in short, an objective standard.

The matter may be illustrated by what took place in the development of certain of the sciences. The secondary qualities involved in the Lockian epistemology—such things as colours, tastes, smells, sounds—lend themselves to a subjective standard, but so long as we confine ourselves to a standard of this kind we cannot be said to treat such matters scientifically. The individual is the sole judge of how a particular sound or colour strikes him, and against his decision there is no appeal. But it seems as if we could not have a science of sounds or of colours based on this individual judgment. Each observer would rely upon his own sensations and would interpret them in his own way. Fortunately in the study of physics it was discovered that certain of the conditions of sensation are constant. When we get a knowledge of wave-lengths, and the laws of refraction and reflection, we have passed from the merely subjective sphere, we have an outside standard, we can compare, abstract, and analyse independently of the individual. 'C natural' has a definite meaning to science, even if there were not a single ear that could hear the sound. It is true that, in the ultimate resort, we cannot eliminate the individual observer. He is too important in ordinary life, and a great deal of the work of science is done after all at his address. How *red* strikes an observer is as important to a scientist as is the exact wave-length that is necessary to produce *red*. The relation between a certain wave-length and a certain sensation is complicated by the individual peculiarities of the sense organs of the individual concerned. In certain respects the science of optics is self-contained, and has a definite objective

standard In certain other respects it depends for its data on individual experiences, and has to content itself with a subjective standard No doubt it can call in the aid of Physiology, a science that has an objective standard of its own, and in this way eliminate a certain amount of subjectivity But in the last resort there is a corner of the field in which no objective standard can be obtained

It is true that in pure mathematics we appear to get into a region where the subjective may be practically excluded altogether, but even here the science of space and time is limited by the fact that it can deal with its data only from the point of view of human limitations And there are certain borderline studies that are mathematical in their essence, yet have a direct reference to our bodily organs Linear Perspective, for example, is usually regarded as a science, indeed as an exact science Yet when we look into the matter we find that Linear Perspective is nothing more than a conventionalised method of treating, in an exact way, the results of individual experience The whole science is really an objective standard by which the ordinary processes of vision may be compared, analysed, and classified Perspective tells us what we ought to see It is not independent of our sense functions, it is only a mode in which the variable subjective is reduced to uniformity by the application of the objective standard Indeed, in the teaching of art there sometimes arises a curious conflict between the subjective element and the objective Students who have studied Perspective before they are called upon to draw real objects set before them, are very apt to draw according to the rules they have learned, instead of observing what is actually before them and reproducing that as it appears to their senses In other words, they set up the objective standard as paramount So markedly is this the case that sometimes the study of Perspective is forbidden till familiarity with model drawing has been attained When a teacher urges a pupil to draw what he sees, and not merely what he knows from the rules of Perspective he ought to see, we have an appeal to the subjective standard The teacher is turning from the science of Perspective to the art of Drawing

This illustration is of particular advantage to us in our present work, because it not only exhibits the subjective standard working alongside of the objective, but it introduces the idea of an *exact* science in relation to our human organs Astronomy is an exact science, and yet the problem of the 'personal equation' shows that even here the subjective must be taken into account The 'personal equation' is, in fact, nothing but the elimination by quantitative methods of the disturbing subjective elements It is by similar methods that we must seek to establish an objective standard in Education The difficulty in this subject is very great Astronomy and Physics touch the subjective only at what may be called the point of application, the point at which they are brought into contact with human life Their subject matter is external, and lends itself to objective treatment In Education the subject matter is human nature, which is so complex and involves such volatile elements that it is almost impossible to reduce its working to fixed laws The same difficulty obviously applies in Psychology Itself a comparatively new subject, Psychology has great difficulty in getting recognition as a science For this there are two main reasons To begin with, Psychology began life as a branch of philosophy, and scientific men regard with suspicion anything that comes from that quarter Besides, there was the less reason to make room for the new subject since it had already a settled place in the hierarchy of studies The second reason is that which interests us here the difficulty of establishing an objective standard The descriptive generalities of Dugald Stewart and Thomas Brown had to give way to something based upon laws that are generally accepted The line of least resistance in seeking for an objective standard in Psychology is to fall back upon a physiological basis It is generally admitted that nerve action can be referred to an objective standard, and by correlating psychic and bodily phenomena psychologists are able to get a series of recognised principles on the physical side that may be easily interpreted in terms of spirit Psycho-physics has at least a plausible claim to rank among the sciences, and the unbridged gulf between mind and matter is conveniently ignored As a matter of fact such a generalisation as the Fechner-Weber law ranks parallel with the laws of Linear Perspective—that is, it is a law that states in an unjustifiably exact way what ordinarily takes place in the individual experience While rejecting the materialistic alliance, Herbart, as a psychologist, deliberately set up a mechanical system of ideas as forces and in this way

established at once an objective standard by means of which all mental process may be understood and manipulated So scientific is his system that he claims that the interaction of the ideas may be calculated in certain cases by a simple application of the rule of three With Herbart, Psychology has certainly been raised to the rank of a science, but unfortunately it has to be admitted that his objective standard has been illegitimately assumed

Just as Psychology utilises Physiology in its effort to gain a standing as a science, so Education is inclined to use Psychology Frequently we hear Psychology described as a science, while Education is relegated to a place among the arts It is natural, therefore, for the educator who wishes to claim rank in science to appropriate the scientific status of his auxiliary science As a matter of fact Education has captured Psychology This is only one of many cases in which a profession has taken possession of an abstract study, and in this way enabled the abstract study to make real progress Theology as a study has gained greatly by the fact that it is a compulsory subject for those who are preparing for a great profession Astronomy owes a great deal to the support it has received from its practical value to navigators Physiology would not be what it is to-day had it not become an essential subject in the preparation for the practice of medicine Physiologists sometimes complain that their subject is hampered by its professors having to waste time in teaching mere medical students, it is well to remember, however, that but for the demands of the medical profession Physiology would have been left to the few private investigators who might be able at their own cost to carry on under adverse conditions the work that is now being done in thousands of well-equipped laboratories In the same way it is greatly to the advantage of Psychology that it has become an essential part of the professional training of teachers The subject is now receiving an amount of attention that it would never have had but for the support of its connection with the profession of teaching But after all a teacher is not a mere psychologist Education is more than applied Psychology If Education is to rank as a science it cannot be in virtue of its use of another study that itself has an insecure foothold among the sciences It must establish for itself an objective standard

Mere quantitative manipulation of the elements of a study, if only carried out on a sufficiently large scale, has a tendency to evolve an objective standard, apart from any deliberate search for such a standard We may gather something from an examination of a standard of this kind that, unexpected and unsought, evolved itself in the ordinary course of educational administration What Binet and his colleagues and followers have been trying to do of set purpose was, to some extent at least, accomplished automatically by the working of the system of individual examinations under the English and Scotch Codes of Elementary Education Binet has drawn up certain tables with the express purpose of testing the intelligence of children at various ages But we are only at the threshold of investigation work of this kind, and the tests cannot be regarded as satisfactory, either in themselves or in their application But they have been drawn up with the deliberate purpose of supplying a more or less objective standard of intelligence Now in the British Elementary School Codes we have the examination requirements from the pupils of different ages set out in a series of tables each corresponding to one of the seven grades known technically as 'standards' The purpose of these tables of requirements was not primarily to determine the intelligence of the pupils, but rather to indicate certain minimum amounts of information that had to be communicated in consideration of a certain money payment Yet these tables bear a generic resemblance to those of Binet, and in actual practice the 'standards' did win acceptance as a test of intelligence The requirements were perhaps less scientifically determined than are those of Binet's tests, but their practical value was very much greater, because of the extremely wide range of their application

When the Codes had been in working order for a score of years it became evident to thoughtful observers that there had arisen a standard of comparison among pupils in elementary schools that was gradually being recognised all over the country It was an objective standard, as was shown by the fact that each of the standards began to have a meaning of its own, apart from the individual school in which a particular pupil happened to be found No doubt there were differences in detail A Standard III boy in one school would be found to have

greater knowledge and skill than a Standard III. boy in another. But the important point is that the phrase 'a Standard III boy' came to have a definite meaning apart from any particular school. It began to be used absolutely, and not merely relatively. Further, if a boy were found to be in a standard lower than his years warranted, people had no diffidence in drawing their own conclusions regarding his ability. It will be remembered that Binet tells us, somewhat vaguely, that if a boy is a year behind others of the same age who have had the same opportunities it indicates that he is duller than the others, but not necessarily permanently so. If, however, the pupil is two years behind the normal test for his age there is a presumption in favour of his being inherently and permanently duller than his fellows. All this is very familiar and indeed commonplace to the elementary teachers who were brought up under the Code Examinations by standards. To tell the truth, M. Binet's tests are regarded with much suspicion by such elementary teachers as have been induced to give them attention. They have the feeling that here we have a University Professor working out as something new a belated scheme that has had its day, and in that day done a great deal of damage. They are afraid that the prestige given to the intelligence tests may encourage the re-establishment of the rigid individual examination system from which they have escaped. All the same, experienced elementary teachers do not deny that the old system did at least have the effect of establishing a generally recognised standard. Their belief is that the standard was not worth what it cost.

It is left for Binet's successors to invent a better scheme than he was able to produce, and in this way to establish an objective standard, at least in respect of intelligence. Such a standard is needed in many connections, but there is one special department of educational administration where such a standard is at present urgently required. Nothing better illustrates the groping of Education after a scientific basis than the present demand for some means of determining which children are 'defective' and which merely dull. So imperative is the need for an objective standard here that it must be satisfied at any price, with the result that the decision is being more and more left to the doctors instead of to the teachers. The cause is not difficult to find. Physiology has already an objective standard, and the doctors are evidently expected to get their results by physical examination. No other explanation is admissible, since they are not only not superior to teachers in their knowledge of the mental reactions of the child, but obviously inferior. At present the argument moves backwards and forwards. Some say: Give the teachers a tincture of physiological knowledge, and then they will manifestly be the best persons to determine the defective stage. Others reply: Give the medical men some little experience of school conditions and the working of the immature mind, and they cannot but be the proper authorities on all questions of intelligence. The important point in this competition for power between the two professions is the implied recognition of the need for an objective standard, and the admission that, at present, such a standard does not exist. Much investigation, experimenting, and verification are necessary before the truth on this particular subject can be reached. But the recognition of the existence of the problem is in itself an indication of progress, and the need for scientific method in working it out is being more fully recognised. From our standpoint it is important to note that we are here dealing with a problem that is distinctly educational, and the bringing in of men from another profession does not make it less so. If the doctor acquires the power of dealing with delicate questions of intelligence, it is because he has learnt to be an educationist if not an educator. Medical men who specialised in this matter would no doubt very soon attain to high skill, since their previous training gives them a very suitable preparation to begin the study of Education. Doctors are consulted regarding 'defectives' mainly for two reasons. First, these defective children are naturally classed in the popular mind with the mentally deranged, and these have always been regarded as peculiarly suitable subjects for the doctor. Further, there exists, without doubt, the implicit feeling in the public mind that the doctor has definite standards while the teacher has only general impressions. But it has to be noted that this invasion of the field of Education by men from another realm of study does not in any way affect the claims of Education to rank as a nascent science with needs and methods of its own. If the doctors can supply Education with an objective standard Education should be very grateful,

but need not abdicate in favour of medicine Education may use the results of both Psychology and Physiology without in any way surrendering its claims to be an independent science We must not, of course, make too much of the distinctions among the sciences Nothing but error can result from seeking to make each of them rigidly self-contained So far as Education is concerned, what we have to seek is that objective standard that we have conceded to be essential to the recognition of a study as a possible science, and this without falling back on the standards of either pure Psychology or pure Physiology

We may learn something from what we have found out about the results of the individual examination system The general tendency of quantitative methods is to eliminate the subjective element Even in the case of marking examination papers experience shows that the use of numerical marks tends to objectify results, and to get rid of some at least of the difficulty involved in the personal equation of the examiners Marking by general impression of a whole paper is much less free from subjective variation Every individual number set down as a mark implies a fresh exercise of the critical power, and when there are many questions there is a compensating principle at work, inasmuch as each impression is recorded as it is made and the addition of the marks produces a balancing in which the latest impression has not the determining influence it too frequently has when a paper is marked as a whole If an examination includes many subjects, many examiners, and a great body of examinees, the subjective element in the marking is, to a large extent, eliminated, and we can deal with the results in accordance with what is practically an objective standard We must not, of course, neglect the fact that after all the whole basis of the results is the judgment of the individual examiner on the material submitted to him This corresponds to the application to real life of any of the physical sciences Here, as in many of the other sciences, we have a surd of subjectivity that can never be got rid of entirely But its disturbing influence can be minimised by the counteracting influences of other forces in the quantitative manipulation of the data

Of late the quantitative method of dealing with educational problems has been greatly developed Karl Pearson's product moment formula has enabled us to make an accurate arithmetical statement of the amount of correlation that exists between series of quantitative data By the application of this formula, and the simpler formulæ of Professor Spearman, it is now possible to correlate a great many facts that were formerly treated as having only a problematic connection with each other If these formulæ produce really reliable results, we have at our command a means of answering definitely and definitively a great number of questions that have hitherto been regarded as the more or less legitimate matter for the professional controversialist The vexed question of 'formal training,' for example, may be set at rest once and for all by a sufficiently extended series of correlations of the results of pupils' progress in certain subjects The peculiarity of this method of dealing with correlations is that once we have handed over our facts to the formulæ, the process passes out of our hands altogether We have only to work out our equations and the results make their appearance Here we certainly seem to have reached an objective standard

Such results, however, are not unnaturally regarded with some suspicion Once the formulæ have been established by mathematical proof they must, of course, be accepted as irrefutable on that side, but their application to educational problems is so mechanical and indeed inhuman that many are unwilling to accept and use them Some people are doubtful whether, in dealing with human beings, it is desirable, even if it were possible, to have an objective standard that eliminates humanity from all human problems It has to be pointed out to such critics that all human problems must begin with the individual and end with the individual All the intermediate process may be carried on in the pure objectivity of quantity, without dehumanising the application of its results This will be kept in view when we deal with the average

Apart from this danger of dehumanising our subject, there are two real possibilities of error in the application of the formulæ First, there is the danger that the investigator may be satisfied with an application to an insufficient number of cases The second danger is that the subjective element may cause error in

the preparation of the data If the first possible source of error be minimised, the second will be practically removed Granted a really wide investigation, there is little room for serious error If a sufficiently large number of cases be examined, and these cases selected under sufficiently varied conditions, the subjective variations will neutralise each other, and a reliable result will be produced It must never be forgotten that the Pearson and other formulæ are merely means of dealing with material already acquired It is only to this extent that they supply an objective standard Many of the recognised sciences are in no better case

The hope of the evolution of Education as a science lies in the proper manipulation of the method of experiment Students of Education have always been in the habit of asking questions, but they have not always waited for an answer Nor have they usually taken sufficient care in making their questions precise They have not laid down with the necessary detail the conditions implied in the question, and when they have reached some answer they have been too often content either to accept it without any verification at all, or with the support of nothing but a few general considerations that seemed to confirm it In the newer educational investigations questions are set out in great detail They are usually limited to one point, and all the relevant conditions are carefully laid down Various control tests are applied during the progress of the investigation, and every precaution taken against the introduction of interfering forces Then when a result has been obtained various confirmatory tests are applied Even when all has gone well so far the result is not regarded as authoritative till the experiment has been repeated with the same results by different experimenters working under different general conditions, though, of course, all the detailed conditions must be precisely the same as in the original experiment

The questions asked are often of a very practical character In the current number of *Child-Study* Mr W H Winch gives an example The question is whether one gets better results in working 'problems' in Arithmetic by (*a*) direct teaching for a certain period in how to work such problems, or (*b*) spending the same period in giving the pupils practice in working such problems Mr Winch gives a very instructive account of all the conditions under which his experiment was carried out, including all the necessary precautions The result is that those who had had the teaching scored an average of 11 1 in the final test, while those who had had the practice scored only 9 2 the group that was taught improving on its preliminary record to the extent of 34 per cent, while the group that had been confined to practice improved by only 11 per cent It is thus demonstrated, at present, that teaching counts for more than practice in the preparation of pupils to do problems in Arithmetic But the fact cannot be regarded as a part of the permanent possessions of the teacher till it is verified by many more experiments in this country and abroad

We have seen that even at our present stage of advancement there is quite a respectable collection of recognised facts in connection with Teaching and Education, and that these are in process of organisation We shall soon have such a volume of well-arranged knowledge as shall meet the first requirement for recognition as a science But while organisation is imperatively needed and must go on, there is an equally urgent need for new knowledge There are hundreds of definite practical questions that are being asked by teachers every day, and unfortunately answered according to individual experience, if not indeed according to individual caprice Some few questions about the memory are now definitely answered, and practical educators have the benefit of the results of experiments, but there are scores of points with regard to memory on which there is still doubt, and yet these are points on which the practical educator must adopt a definite line in his daily work He cannot postpone his decision he must do one thing or another, and in the meantime he has no standard Such investigations as are being undertaken by the committees of this section are helping to increase the total body of knowledge at present available It is true that hitherto these investigations have been mainly concerned with psychological matters, and certainly our store of psychological knowledge is not so great as to warrant any complaint at the concentration on this aspect But it is pleasant to note that this year we are having a report on more distinctively pedagogic matters There could be no more useful subject of inquiry suggested than an

investigation into the questions that are most urgently demanding answers at this time among the practical educators of the country. To discover and classify these, and then to correlate them with the various investigations that are being made throughout the world, would be to render a very practical service to the study of Education. The truths thus acquired and recorded could be fitted into the mass already at our disposal, and the result would be a great strengthening of that objective standard that is so essential to the independent progress of our study.

Education ranks with a group of studies that deal with humanity in its various aspects. Psychology naturally is the science that underlies them all, since it is the abstract study of human nature which is their raw material. But Politics, Economics, Sociology, Eugenics, all claim to be sciences, and if we probe into their standards we find that they are largely statistical. It is quite possible by careful investigation among the subject-matter of these sciences to organise a system of general principles based upon averages obtained from a very wide field of investigation. These principles are of very general application, though they may not enable us to prophesy in individual cases. This, indeed, is at the root of a great deal of the criticism levelled at the claims of Education to rank as a science. A parent or an education authority presents a boy to an educator and calls for a prophecy. The educator must decline, since he cannot honestly prophesy in an individual case, though he may be prepared to venture on a reasoned statement of what is likely to occur in the boy's educational career. The educator is, in fact, in precisely the same position as a medical man called in to a case. He can prophesy, but only in general terms. In both cases it is the application of general principles to a particular case.

This raises the whole question of the value of the average in matters of Education. Psychologists in addressing teachers are beginning to warn them that the average is only an abstraction and really does not exist. We are told that what the teacher has to concern himself with is 'the living child here and now before him,' and he is accordingly warned against the insubstantiality of the elusive abstract. But this is to confound two distinct things. It is true that the teacher must always deal with a living pupil here and now before him. But in his dealing with that living pupil he has to apply a paid-up capital of knowledge of men and of boys in general. He must seek to understand the living boy by the aid of knowledge previously acquired, and this knowledge is represented by the average. The master may be unable to prophesy with certainty how Jones minor will act under certain specified conditions. But from a knowledge of Third Form boys in general he can make a guess that is very likely to hit the mark. The teacher who applies his knowledge of the average Third Form boy to the minor Jones without modification to suit Jones's case, acts unintelligently; but the possibility of blunders by a dull master does not reduce the value of the knowledge of the average in the hands of one who is capable. The concept of the average boy as it is developed by experience and study in the mind of the master forms a standard by which other boys may be estimated. This standard is partly subjective, partly objective. In so far as the standard is acquired by the personal experience of the master it is subjective. The unreasoned but very effective knowledge of boy nature that enables an efficient master who is guiltless of any acquaintance with educational theory to know how a boy is likely to act under given circumstances results from the training of experience, and is peculiar to its possessor. On the other hand, the knowledge of boy nature that has been acquired by deliberate study and by experiment is something that has an existence independent of the individual. It is objective, or at any rate has an objective bias.

We must distinguish in practice between the average and the type. The average boy may have no existence in reality; he may be a pure abstraction; but the type is concrete, and may be regarded as the embodiment of all the essentials that go to make up the average, with the addition of certain qualities that must be present in some form or other, though the particular form is immaterial. The average is to the type as the concept is to the generalised image. The type may form a very useful standard for masters whose tendency is strongly towards the concrete, but the average has a special and a different value, and in capable hands is more effectively applied because it is of a wider range. To con-

sider a class as made up of types tends to break up the class feeling, and make the master think of his pupils as a mere group of separate individuals. Undoubtedly the master must in certain connections think of his pupils as individuals, but in other connections he must deal with his class as a whole, as a psychological unit.

This introduces one of the most striking developments of modern educational theory. The older psychologists treated their subject as limited to the study of the mature human individual. The introduction of the idea of development led to the founding of genetic psychology with its consideration of the individual at his various stages. A further advance is marked by the appearance of collective psychology which carries the study of the individual into his relations with other individuals. Naturally both changes were of the greatest advantage to education. The first gave scientific guidance to the popular movement known as Child-Study, the second suggested the scientific study of the class as a collective organism. It is true that this collective psychology is at present in its infancy. But while we owe much to the French psychologists with their dazzling exposition, we are glad to turn to our more solid McDougall for the best scientific basis available for a sound collective psychology. The material he has supplied is waiting to be worked up from the educational side. His statement of the relation between the instincts and the emotions and his manipulation of Mr. Shand's theory of the sentiments provide tempting material for the establishment of an objective standard in connection with the training of the individual character and the interaction of individual characters in groups. Naturally the results must be expressed in averages, and equally naturally there will be a complaint from certain practical educators. What is the use, it will be asked, of information about how classes in general act? What we want to know is how this particular class before which I stand is going to act. But this is to confound the practice of a science with the science itself. There must always be an intelligent intermediary between the principles of a science and their application to the affairs of life. In this respect the nascent science of Education differs in no way from those that are more fully developed. The educator who prides himself on being specially practical is frequently very unreasonable in his demands from educational theory. He is rather apt to complain that it does not supply him with sufficiently detailed instructions. What he wants is a series of recipes which, if scrupulously followed, will inevitably produce certain specified results. But such men take a very humiliating view of their profession. So far from seeking this spoon-feeding, they should rejoice that their work demands the exercise of intelligent initiative. Herein consists, in fact, the dignity of the educator's office. He must be master of the organised knowledge that Education has acquired, and must have the power of making the appropriate application of that knowledge to every case as it arises. To assist him in avoiding error he is entitled to look for an objective standard at the hands of those who make Education their special study, but for the use of that standard he must himself accept the full responsibility.

The following Report and Paper were then read:—

1. *Report on the Influence of School-books upon Eyesight.*
See Reports, p. 295.

2. *A Plea for supplementing Small Scholarships.*
By Professor MARCUS HARTOG, *D.Sc.*

Scholarships have two functions—(1) providing a supply of qualified men for the professions that need a costly training; (2) affording adequate training for men of exceptional promise to fit them for doing their best work in the world. The majority of scholarships are of value insufficient for this purpose unless supplemented by contributions from parents, relations, or friends in easy circumstances. Failing these, the scholar is cramped at every step by the lack of means to buy books and instruments, to profit by the social education of the university. If he

himself earns money by teaching, unless he have an iron constitution he must sacrifice either his own improvement or his health Parsimony in living is dangerous to present health and future conduct in life The remedy suggested is the provision by individuals of funds to be administered privately through presidents or professors.

FRIDAY, SEPTEMBER 6

Discussion on Vocational Education in Schools

(1) *Vocational Training in Edinburgh* By J W Peck

This paper was divided into three parts—(1) the vocational characteristics of Edinburgh, (2) how the educational system is related to these characteristics, and (3) future lines of development

As regards (1), reference was made to the national census of 1911, and a special educational census of young persons taken by the Edinburgh School Board in 1910 The requirements of the city, as shown by these figures, were considered

Out of about 17,000 persons between fourteen and eighteen years of age, 12,000 undergo some form of vocational training or of higher education This is about two thirds of the total between the limits The methods by which this is attained under a voluntary system were described Advantage has not yet been taken of the compulsory powers given by the 1908 Education Act in Scotland

As to the operation of the juvenile labour exchange in Edinburgh, about 4,500 children leave the schools each year, and of this number about 2,800 obtain employment The system acts on the total number, and advice as to vocation and appropriate education is given by expert officers, and by the issue of special pamphlets on the various Edinburgh occupations

The educational system provided aims at giving (*a*) Training for occupation; (*b*) training in the English language, (*c*) training in citizenship; and (*d*) physical training Under the voluntary system each of these elements cannot be insisted on in their proper proportion, and balanced courses are not taken by the majority of the pupils

Reference was made to the practical workshops provided for engineers, brass-finishers, tinsmiths, moulders, pattern-makers, cabinet-makers, joiners, plumbers, upholsterers, plasterers, tailors, and those engaged in domestic work A complete equipment of such workshops will be in due course provided for the city Advisory committees deal with the equipment of the workshops and the selection of the practical teachers

Only about 30 per cent of the 10,000 pupils in the Board's continuation classes take the course in English language, in citizenship only about 2½ per cent; and in physical training only about 11 per cent

Reference was made to the teachers—about 490 in number Of these, 270 are professional teachers and 220 are engaged in some occupation or trade during the day Methods of training the trade teacher in educational methods, co-ordination of the Board's continuation classes with the Central Institutions of the city in science, art, domestic economy, agriculture, and veterinary science, were referred to About 230 out of 1,000 pupils who qualify in the year pass on to these higher institutions

Criticism of the system as it stands at the moment is directed to four points —

(1) Some system of compulsion should be adopted, as it is doubtful whether the remaining 5,000 will be touched by voluntary methods With this, of course, must go a reasonable half-time system of work at occupation

(2) The compulsion should not be merely directed to enforce attendance It should have regard to the need for securing the four elements of continuation class education referred to above—viz, instruction in vocation, instruction in English, instruction in citizenship, and in physical training With the last there should go medical inspection As an alternative to conscription, the physical

training might include a certain amount of military training The need for directing attention to the question of training in citizenship—methods and text-books—requires close examination

(3) The need for adopting the two-session day for teachers who at present work full time in the day school and in the evening as well Similarly the need for dealing with the non-professional teachers who are working at their trade all day At the same time, all trade teachers must remain in contact with their trades, or else the instruction tends to be theoretical and stereotyped

(4) Development of the system of supervision of the young workers The methods of the Care Committee in the elementary school should be extended with appropriate variations to the continuation classes, so that advice as to occupation, education, and general activity of the young people should always be available This advice is best given by local committees in close personal contact with small districts These committees should focus the various specialised activities, such as boys' clubs, guilds, church organisations, athletic organisations, and the like The committees which give the supervision should always be dependent on the statutory Education Authority, so as to have the backing of its prestige, legal powers, permanence, and funds

(ii) *Vocational Education from the Point of View of a County Area* *By* J L HOLLAND, *B A*

(iii) *Vocational Education in Girls' Schools* *By* MISS FAITHFUL

The Report on the Curricula and Educational Organisation of Industrial and Poor-Law Schools was then read —See p 319

MONDAY, SEPTEMBER 9

The following Report and Papers were read —

1 *Report on the Mental and Physical Factors involved in Education* See Reports, p 327

2 *Discussion on the Psychological Processes involved in Learning to Read, Write, and Spell*

(i) *The Psychology of the Reading Process* *By* F SMITH See Reports, p 330.

(ii) *The Methods of Teaching Reading in the Early Stages, with special reference to the Look-and-Say Method* *By* B DUMVILLE, *M A*

I BRIEF SKETCH OF THE CHIEF METHODS

(1) The Alphabetic Method
(2) The Phonic Method—Miss Dale's System
(3) The Look-and-Say Method—The 'Sentence' Method

II. CONSIDERATIONS FOR AND AGAINST THE LOOK-AND-SAY METHOD

(1) *For*

(a) *Experiments* show that *all* practised readers proceed by 'Look-and Say' It is admitted, even by such supporters of the 'Phonic' method as Professor Meumann, that 'the object in reading is the reading-type of the adult' Should we not, therefore, adopt 'Look-and-Say' as far as possible from the beginning?

(b) *All that we know of genetic psychology* is opposed to analysis in the early stages Cognition proceeds from the grasping of indefinite wholes to a knowledge of their details, and from these details to a clearer and more definite knowledge of the wholes This process is provided for in most adequate fashion by the 'Look-and-Say' method Even if analysis is not insisted upon by the teacher, it takes place sub-consciously in the minds of intelligent children

(c) *The examination of results* shows that there is much more rapid progress in the early stages by 'Look and-Say' than by 'Phonic' methods

Mr E J Gill, of the University of Sheffield, obtained the following *time* results with two unseen extracts (called A and B respectively) in three schools (X being a 'Dale' school, Y a more ordinary 'Phonic' school, and Z a 'Look-and-Say' school of the 'Sentence Method' type) —

—	Class Average Time				Mean Variation			
Extract	A		B		A		B	
	Min	Sec	Min	Sec	Min	Sec	Min	Sec
School X	1	49	1	46$\frac{4}{5}$	0	53$\frac{1}{5}$	0	49$\frac{1}{5}$
School Y	1	28$\frac{4}{5}$	1	42$\frac{1}{5}$	0	29$\frac{2}{5}$	0	39$\frac{2}{5}$
School Z	0	37$\frac{1}{5}$	0	39$\frac{3}{5}$	0	12$\frac{3}{5}$	0	13$\frac{1}{5}$

I myself obtained results both with respect to *time* and *mistakes* in an experiment in learning to read with a new alphabet (that of the *Association Phonétique Internationale*) conducted with older children Extract A contained none but words previously introduced to the children Extract B contained many new combinations of the same sounds, and, if no analysis had taken place in the minds of the 'Look-and-Say' pupils, would have rendered the results of the 'Look and-Say' section hopelessly inferior to those of the 'Phonic' section The following are the results —

Standard VII of an Elementary School

(Thirty six pupils divided into two equal sections)

Time devoted to learning in both cases, thirty minutes

Section Tested ↓	Extract A				Extract B			
	Average Time in Seconds	Mean Variation	Average Number of Mistakes	Mean Variation	Average Time in Seconds	Mean Variation	Average Number of Mistakes	Mean Variation
Phonic	189$\frac{4}{5}$	42$\frac{1}{5}$	9	3 1	139$\frac{3}{5}$	39$\frac{1}{5}$	9	1 1
Look-and-Say	127$\frac{1}{5}$	30$\frac{1}{5}$	7 2	3 6	97	21$\frac{4}{5}$	8 3	2 4

Form VI of a Secondary School

(Twenty-five pupils divided equally, the odd one being put in with the 'Look-and-Say' Section)

Time devoted to learning in both cases, twenty-five minutes

Section Tested ↓	Extract A				Extract B			
	Average Time in Seconds	Mean Variation	Average Number of Mistakes	Mean Variation	Average Time in Seconds	Mean Variation	Average Number of Mistakes	Mean Variation
Phonic . .	60$\frac{2}{5}$	11$\frac{3}{5}$	2 6	1 9	43	6$\frac{1}{5}$	2 7	1 2
Look-and-Say .	48$\frac{4}{5}$	8	1·8	1 2	46$\frac{3}{5}$	11$\frac{2}{5}$	3 8	1·8

Professor Schumann, of Zurich, mentions several instances of children, both feeble-minded and intelligent, who have learned to read more readily by the 'Look-and-Say' than by the 'Phonic' method; in particular, the case of a normal child who 'in three months, with half-an-hour's teaching and half-an-hour's homework per day, got through the whole of the first year's work in reading.'[1] Many other instances could be cited.

(d) *Meaning* is prominent from the first when the 'Look-and-Say' method is adopted. With the 'Phonic' method, however, the consideration of sounds must obscure everything else in the early stages. Moreover, the sounds in question (the powers of the letters) are most uncongenial material for children—if not for adults. With the 'Look-and-Say' method, therefore the true object of reading can be obtained in some degree in the earliest stages. *A real interest in literature* can be cultivated from the first, whereas with the 'Phonic' method there is a grave danger of killing this interest by the laborious preliminary work with meaningless elementary sounds. It is to be further noted that in fluent reading the meaning already gathered facilitates further reading. 'The direction of the apperception proceeds in most cases from an anticipation of the meaning as determined by the context.'[2] In such cases we do not need to scrutinise every word. Now this facilitation of the reading process can begin much more early with 'Look-and-Say' children, who gather more meaning than 'Phonic' children, and who may indeed be allowed to 'guess' whenever they are in doubt.

(e) Reading can be an *occasional* and pleasant variation of the school work during the early stages, when the 'Look-and-Say' method is adopted.

(f) *The unphonetic character of English spelling* renders the 'Phonic' method much more difficult, and the 'Look and-Say' method much more suitable, than is the case with a language like German. It is sometimes stated by 'Phonic' enthusiasts that only about a quarter of our words are irregularly spelt. It would be nearer the truth to reverse the proportion, and admit that three-quarters of our words are more or less irregular in spelling. The test can easily be made.

(2) *Against.*

(a) The *speech-training* of the 'Phonic' method is lacking in the 'Look-and-Say' method. To hear some 'Phonic' enthusiasts one would imagine that the child on arrival at school *cannot speak at all*. Good pronunciation is, of course, most necessary. But it is largely an affair of imitation by ear, and if it were attended to *at all times*, there would be no necessity to *concentrate* upon it in the reading lesson. It is all the more important to avoid this in the early stages because the children require all their available attention for the difficulties of word recognition. *One thing at a time!* should be the motto with young children.

(b) *New words* are said to present an insuperable difficulty to 'Look-and-Say' children. But experiments have shown that the power to attack new words develops very rapidly. And even where in the early stages it is wanting, *the teacher is there to help.*

(c) *Guessing* is said to be fostered by the 'Look-and-Say' method. But this is not really 'guessing' in the usual sense. It is what Meumann has described as 'an anticipation of the meaning as determined by the context.' And it is in itself a proof that real reading has been performed with the foregoing text. Errors will tend to correct themselves. But, once again, *the teacher is there to help* in the early stages.

(d) *Imperfect perception* of words occurs with the 'Look and Say' method. Words of similar appearance are often confused. In this difficulty the 'Look-and-Say' method can borrow a trick from the opposed method. Careful analysis and synthesis may take place in these cases. To improve, however, the sharpness of perception of *word-wholes*, tachistoscopic exercises can be performed. I have myself devised a crude form of apparatus for this purpose.

[1] 'Psychologie des Lesens,' *Bericht uber den II. Kongress fur experimentelle Psychologie* (1906), p. 158.

[2] Meumann, *Vorlesungen*, II., pp. 264-5.

(iii) *How Children learn to Read.* *By* BARBARA FOXLEY, *M.A.*

English children are taught to read in one of three ways:—

1. *The Spelling Method.*—C-a-t, cat; d-o-g, dog. This method, banished from schools under Government inspection, still flourishes in many other schools, and it occasionally intrudes itself into most schools through the well-meant but mistaken efforts of parents and grandparents to supplement the work of the school-teacher.

2. *The Phonic Method.*—The child is taught, not the names of the letters, but their sound-values, singly or in combination, *e.g.*, o-x, ox; b-ox, box; f-ox, fox. This method is generally adopted in schools under Government inspection.

3. *The Look-and-Say Method.*—The child is not taught to analyse the word in any way, but to use it in some practical connection. *E.g.*, a picture of a canary gives him the clue to the word printed under it; a command, 'Geoffrey, feed the canary,' is read and carried out. The child soon learns to 'look and say' the word or phrase in other contexts. Very often phonic analysis is introduced when the child can read fairly fluently. This method has long been used by some of the most thoughtful teachers; recently it has attracted much attention in America, and it is now being used in an increasing number of English schools.

Individual children, and even classes of children, taught on any one of these methods, learn to read quickly and well. This has usually been attributed to some variable condition, such as a zealous teacher or the child's desire to learn.

A good many attempts have been made to determine the average time spent in learning to read, but the results are very conflicting. The observations I have made have been directed, not to the results of the different methods, nor yet to the processes carried out by the teacher. I have tried to observe and record the processes carried out by the scholar. By the courtesy of various head-mistresses and class-teachers I have been able to watch the reading lessons and to record what took place; the result of my observations may be briefly stated. There are three ways of teaching reading, but only one way of learning to read. So long as the teacher says, 'Spell it,' or 'Sound it,' when the child is confronted with an unfamiliar word, so long as she writes its letters or syllables on the blackboard, the child follows her lead, though it is often clear from his look and voice that he does not get the sense of the word he pronounces correctly. Left to himself he scarcely ever uses either method of word-analysis, but falls back on the method of finding a clue in the context, and so soon as he gets into the habit of doing this, so soon does he really begin to read with understanding and with fluency.

At a later stage I have found children taught on the 'Look and Say' method adopt a method of analysis, but not a phonic method. A child notices that two words, *e.g.*, window and windy, look alike; he announces his discovery to the class, and it becomes a favourite pastime to look out for such likenesses; how far this is accompanied by attention to sound likenesses I cannot say. I have not observed any instance of spontaneous phonic analysis in connection with printed symbols, though children delight in the sound of rhymed words.

If my observations are correct it seems that children do not learn to read by means of analytical methods, but in spite of them.

(iv) *The Psychology of Writing.* *By* Dr. W. BROWN.

See Reports, p. 337.

(v) *Movements in Handwriting.* *By* ROBERT R. RUSK, *M.A., Ph.D.*

The demands which society makes on the schools in regard to the subject of handwriting have changed within recent times. A generation ago, the average member of the community was not called upon to do much writing, and what writing was done was usually intended to serve some permanent purpose. At present the requirements of society in regard to the amount of writing demanded of its members are considerable. This necessitates that the writing should be executed with the least expenditure of energy and that it should be performed

with rapidity. Writing of a high degree of legibility is not now required; this can readily be secured by mechanical means The schools, failing to recognise these changes, may be using methods well suited to secure a writing which is beautiful in form, but which demands for its execution a considerable expenditure of time and energy. These methods may, however, be ill adapted to attain the present aim of 'an easy, fluent, well co-ordinated movement, producing letters of a fair degree of legibility', they may even be positively harmful when turned to the latter purpose, occasioning writers' cramp and other evils It may even be the case, as has been maintained by Thorndike in regard to American schools, that we are training the pupils to write too well The change in the aim of handwriting implies that, in teaching, consideration has to be withdrawn from the product and given to the movements in handwriting It may also become necessary to take into consideration the mental processes accompanying and directing the physical movements Here, however, we shall confine ourselves to the treatment of the movements

In writing three forms of movement are involved —

(1) The finger movements usually employed to form the rounded elements of letters, and, in some cases, also the upward and downward strokes.

(2) The movement termed pronation, which consists in rotating the hand, so that it tends to lie flat on the palm

(3) The movement in the shoulder joint and at the elbow, which admits of the passage of the hand across the page.

Before we can decide what method should be adopted in the teaching of writing, we must ascertain what is the easiest movement required to form the letters A simple contrivance, devised by Judd, enables us to isolate the movements of the hand from those of the fingers and to obtain records of the former Thus for any style of writing we can register how much finger movement is involved. What remains to be determined is the question whether, for the formation of the letters, the finger movement or the hand-and arm movement is the easier, and this question can only be determined by laboratory experiment Some would solve the question off-hand in accordance with the prevalent notion that the finer muscles do not develop till later than the larger muscles, without attempting to prove that this holds for the muscles involved in writing We require experiments with pupils of different ages, and with adults, to determine the ease or difficulty of the finger movement, as compared with the hand-and-arm movement Recent investigations by Freeman at Chicago indicate that the hand-and-arm movement should be used to form the upward and downward strokes, and that the rounded elements should be executed by the finger movement This method is said to give better results than the exclusive use of the hand-and-arm movement The exclusive use of the finger movement does not seem to have been contemplated by the investigator, and, as this is the alternative presently practised in this country, the repetition of the experiments becomes necessary

The second movement, that of the wrist to keep the palm of the hand flat on the paper, seems to be quite unnecessary It likewise occasions a needless expenditure of energy, and retards the rate of writing without conferring any advantage in legibility The movement of pronation should consequently be dispensed with and writing on the side of the hand should be allowed

The easiest movement of the arm across the page is an outward movement almost at right angles to the forearm If this movement were adopted, and the paper placed parallel to the desk, the writing would run upwards To admit of the easiest movement of the arm, and at the same time to keep the lines regular, it is necessary to tilt the paper until its base is almost at right angles to the forearm

The most natural direction for a downward stroke is towards the body This would result in vertical writing if the base of the paper were placed parallel to the edge of the desk, but if the paper is tilted, as we have already recommended, and the downward stroke is made towards the body, the resultant writing is inclined to the right in the same degree as that at which the paper is tilted. Thus writing with a slope is the writing easiest to execute.

We are but at the beginning of research in handwriting; the experiments which have been already made elsewhere require to be repeated in this country, and the investigations extended to include aspects not yet considered. For research in handwriting we cannot depend on psychological laboratories, the determination of the problems which have a direct bearing on school practice demands the institution of independent pedagogical laboratories.

3 *The Scotch Education Department*
By Principal Sir J. DONALDSON, *LL D.*

The subject which I am to discuss is the anomalies which arise from the part assigned to the Education Department in the management of educational affairs in Scotland In the Education (Scotland) Act of 1872 occurs the definition 'The Scottish Education Department shall mean the Lords of any Committee of the Privy Council appointed by her Majesty on Education in Scotland' This Scottish Education Department was entrusted with most important duties and powers It was to arrange the distribution of the Government grant for education in Scotland It was to prepare a Code to regulate this distribution The appeal was consequently to be made to it if the legal bodies dealing with education found any difficulties In fact, it had almost complete power over all the arrangements connected with education Yet this Committee almost never met Many years must have elapsed in which it had no meeting There was no quorum fixed for the meeting, and as far as was known the Committee never recorded any of its actions in minutes This has been the case down to the present day The Committee had for its President the President of the Privy Council, and the Scottish Secretary was Vice-President The President of the Committee has taken no part in Scottish education, probably he does not know that he is President of it, or if he does it is only by his having to sign some official document The Vice-President, as Scottish Secretary, has a very large amount of most varied business to discharge, and he may or may not take an active part in the management of education in Scotland In the Act it is mentioned that the salaries of the officers and servants of the Scottish Education Department shall be fixed with the consent of the Lords of her Majesty's Treasury It is these officers and servants who have been the real managers of Scottish education If the Scottish Secretary has time and takes a deep interest in education, he may be the controlling and guiding spirit in the management, but if he cannot spare the time, then it is the officers and servants of the Department that must do the work These officers are a permanent secretary, with a number of subordinate secretaries or clerks, and a body of inspectors Sometimes the Scottish Secretary has not been on the most friendly terms with the permanent secretary and has not consulted him much, but at other times he has left the entire work of control to the permanent secretary When a document issues from the Scottish Education Department no one can be certain whether it is the work of the Scottish Secretary or the permanent secretary or some of his subordinates It is not possible to fix the responsibility on anyone It is needless to say that such a state of matters is unsatisfactory, and various evil consequences have resulted from it. At present the state of education in Scotland causes much anxiety among many Scotsmen There is no doubt that the Department succeeds in giving some kind of education to a very large proportion of the population, and it is always strong in statistics, but whether the education of these is good, as compared with that of other countries, and is calculated to produce thoughtful and contented citizens, is a different question The policy of the Department during a considerable number of years now has been to carry out a system which has been borrowed from Germany, but which is to a considerable extent destitute of the safeguards which can secure a thoroughly sound education A change, therefore, is imperatively required, and it is plain that the change should be to make the Committee constituting the Education Department a reality The members of it should be responsible for all the documents issued in their name They should be men who have a wide knowledge and deep interest in education The Committee

need not be large, but it should contain a certain number who have had actual experience in teaching in schools and in the training of teachers. It would consequently be necessary to abandon the plan of making the Committee consist only of Privy Councillors. Such a Committee would be invaluable to the Secretary of Scotland if he were to be bound to take upon him the duties of Minister of Education for Scotland. Such is the method adopted in all the countries where the education of the people has reached a high standard of excellence.

TUESDAY, SEPTEMBER 10.

The following Report and Papers were read:—

1. *Report on the Overlapping between Secondary Education and that of Universities and other places of Higher Education.*—See Reports, p. 338.

2. *A System of School Leaving-certificates, with special reference to Scotland.* By J. STRONG.

A school leaving-certificate should be based upon the satisfactory completion of a school course; it should also function as a passport to further education. These presuppose a clear definition (1) of the whole field of education, and (2) of the links connecting the various elements in it.

In general the primary school course does not end where the secondary begins. In consequence, while every facility should be provided for the transference of the abler pupils at the proper time from one school to the other, the leaving certificate of the primary school is not necessarily the link connecting the two, but rather the link connecting it to a trade school or a continuation school.

It would be a gain to education if a permanent council, representing various educational interests, were created to consider and pronounce authoritatively upon courses of studies, and in particular devise a standard formula for a secondary course. With a generally recognised norm or standard, secondary education would gain not only in definition and simplicity but in character. The application of certain generally accepted principles is required in the first instance; experience would give the rest. Increase of individual differences with age means increase of specialisation as the school course advances. The danger of premature specialisation, and the possibility of late development of 'bent,' indicate the advisability of an intermediate period in the course, in which there should be modified or restricted specialisation. In any case there will be a constant process of adjustment. Some subjects should be compulsory, others optional. The principle may be enunciated that every secondary school course should provide in its compulsory part characteristic subjects drawn from both humanistic and mathematical or scientific studies. According to the optional subjects selected there would be various types of leaving-certificates. These would all guarantee the satisfactory completion of a course of secondary education which, in its compulsory part, provided the essentials of a sound secondary education. In particular a leaving-certificate, while giving the right of entry to a university, should give the right to enter upon a particular course of study there only in so far as it testified to fitness for such study.

The entrance qualifications to the various professions and the grades and branches of public service could readily be correlated with the standard course. Business firms might define their requirements by some stage in the course.

These principles and conclusions are in a measure exemplified in Scotland. Secondary education is assumed to begin about the age of eleven or twelve and extend over five or six years. There is an intermediate course of three years, followed by a post-intermediate or leaving-certificate course of two or three

years. The intermediate curriculum includes seven subjects, English, history, geography, mathematics (including arithmetic), at least one language other than English, science, and drawing. The post-intermediate includes at least four subjects, three of which must be English (including history), one language other than English, and mathematics *or* science. The intermediate certificate crowns the one course and the leaving-certificate the other. The award depends upon a written examination, a class oral examination, and the teacher's opinion. The papers are set on two standards, and excellence in one subject may compensate for deficiency in another.

The intermediate certificate indicates the satisfactory completion of a well-balanced course of general education, suitable for those who leave school at the age of fifteen or sixteen. It also acts as a passport to certain technical institutions and continuation schools. The standard of examination practically precludes the study of more than two foreign languages in the course.

Leaving-certificate courses may be classified as general, linguistic, mathematical, scientific, artistic, or musical. There is no difficulty in selecting a group of subjects which meets the entrance requirements of the universities.

3. *Discussion on the Present Position of Mathematical Teaching.*

(i) *The Reform of the Teaching of Trigonometry.* *By* T. PERCY NUNN, *D.Sc.*

Few systematic attempts have been made to reform school trigonometry in the spirit of Professor Perry's teaching. Yet in no branch is it easier to present mathematical truths as instruments of investigation and 'intellectual control.' What is chiefly needed is a complete departure from the traditional curriculum and method. To begin with, trigonometry should no longer be regarded as a separate 'subject,' but should be incorporated in algebra. The inevitable effect of making it a distinct branch has been an over-elaboration of its formal side. This, in turn, has made it an 'advanced' subject, accessible only to specialists. There is no logical or pedagogical justification for this procedure. *All* boys and girls should study the sine and the tangent just as they study the square root or the cube—namely, as a means of appreciating the quantitative side of certain matters of wide human interest. The author has experimented with a programme of topics under the following heads: (1) surveying problems, (2) navigation problems, (3) map projections, (4) the analysis of wave-motions and other periodicities. The method is concrete and practical throughout and ignores the academic distinction between plane and spherical trigonometry.

(ii) *The Present Position of Mathematical Teaching.* *By* P. PINKERTON, *D.Sc.*

We are beginning to learn that current ideas regarding the teaching of mathematics are very like current ideas in other provinces, and that the movement towards reform is an index of the spirit of the times. It is fairly safe to say that mathematics used to be regarded by many as consisting of a body of sound doctrines logically articulated and appealing only to minds specially fitted to receive them. Literature, on the other hand, was supposed to be more human, more adapted to the tastes and capacities of the many. One of the results of looking closely into these matters, without subservience to tradition, is the conclusion that a genuine appreciation of language and literature is just as rare as a genuine appreciation of mathematics, and that the aims and ends of teaching are in both cases very much alike.

A good though simple poem, such as Wordsworth's 'Daffodils,' serves to illustrate the various stages in the growth of ideas just as much as a good piece of elementary mathematics. The first verse describes a scene, the second the beauty of the scene, in the third the mind is attracted and interested, and in the fourth the scene is treasured 'in the mind's eye.' The equation $3x + 4y = 7$ displays a scene of related x's and y's; the beauty of the scene is revealed when

these are framed with reference to axes; the mind becomes interested in the linear arrangement, and there follows finally the demonstration of the remarkable equivalence of line and equation

Comparison with the mere proof that a linear equation represents a straight line shows that current ideas regarding reform are on sound lines The danger used to lie in teaching formal conclusions with little or no account of their growth It would be small gain if we fell into the opposite danger of teaching to look without observing or to observe without inquiring. In trigonometry, for instance, the formula $a = 2R \sin A$ and its proof represent the last stage, the preceding stage is the observation that we could draw and measure a chord of a circle if we knew the diameter of the circle and the angle subtended by the chord at the circumference, and this is preceded by beholding the beautiful scene of equal angles in the same segment of a circle In descriptive geometry we must *see* the line given by its plan and elevation or the plane by its traces Not till it is noted that from the traces of a plane a joiner could mechanically construct the scene, that the plane is there, can there be any observation of such a thing as the real angle between its traces, far less any inquiry into its determination, or any sound understanding of what a text-book conveys by the heading, 'Given the traces of a plane, to find the real angle between the traces,' and the corresponding construction The preliminary study of the calculus requires the survey of scenes where $\delta y/\delta x$ and Σydx are matters of observation and interest before the notions of a limit and dy/dx and $\int ydx$ are reached Otherwise we may know about dy/dx and $\int ydx$, but we do not know them, at any rate we do not know them in the sound sense of knowing the spirit through the letter

(iii) *The Present Position of Mathematical Teaching*
By William P Milne, *M A , D Sc*

In passing in review the changes that have taken place in the teaching of mathematics throughout the country during the last ten or twenty years, one has to consider not only the instruction given to the rank-and-file of mathematical pupils, but also that given to those of higher endowments, seeing that for a nation's educational efficiency it is essential to train carefully the average person and to train equally carefully the expert It is found that at the present moment practically all the best pedagogic thought of the country is being directed towards rendering mathematics at once useful and educative to the pupil of average attainments, while very little is being done for those who are being definitely trained in the more advanced branches It is here maintained that most of the methods discovered and applied with such conspicuous success to the teaching of elementary mathematics can be extended in scope and modified in application so as to improve the teaching of the higher mathematics, and bring a larger proportion of the more difficult branches of the subject within the powers of comprehension of the general body of the more advanced pupils than is at present possible The published views of such distinguished teachers as Tait, Chrystal, and Hobson support this hypothesis

If we consider the teaching of the higher mathematics given in the secondary schools to scholarship candidates, we see that the following difficulties at once present themselves and militate against efficient teaching :—

(1) No systematic effort has ever been made by secondary teachers carefully to scrutinise the schedule of knowledge required of scholarship candidates, and to discover what could be best omitted and what could advantageously be added

(2) The subject has left the stage when it is easily within the teacher's grasp, without any private study Owing to the length and stress of his official routine, very little time is left him to keep abreast of the latest developments of the subject as it leaves the hands of the great masters and investigators

(3) Owing to the labour of preparation and the small pecuniary returns, text-books covering the ground of the scholarship work are rarely published, and continue to be used when long out of date

(4) Detailed discussions as to the best methods of teaching such difficult subjects as Limits, Virtual Work, Homography and Involution, &c , have never been carried out.

That secondary teachers are beginning to feel some active steps should be taken to remedy these defects is shown by the recent publication of Mathematical Monographs, a book in which busy schoolmasters can find succinct and lucid discussions from a philosophical standpoint of the subjects they have to deal with in teaching scholarship work. Furthermore, there is a very suggestive paper in the *School World* of last June by Dr. Charles Davison, of Birmingham, on Mathematical Essays historically and pedagogically treated.

In conclusion, how to get and keep the pupils' interest amidst the discouraging difficulties of the more advanced mathematics, and how the master shall keep his own knowledge fresh and thoroughly up to date, constitute a fertile, almost untraversed, field of pedagogic inquiry.

(iv) *The Present Position of Mathematical Teaching.* *By* W. D. Eggar, *M.A.*

Section M.—AGRICULTURE.

President of the Section.—T. H. Middleton, M.A.

THURSDAY, SEPTEMBER 5.

The President delivered the following Address:—

Early Associations for Promoting Agriculture and Improving the Improver.

The honour which has been done me by the Council of the British Association in electing me to be President of the new Section, 'Agriculture,' carries with it as its first privilege the opportunity of congratulating those officers of the Sub-sections who have been the means of securing for agriculture the place which its students have long coveted in the meetings of our great Association for the Advancement of Science. Sir Horace Plunkett, than whom no one has shown a better appreciation of the advantages of association for the improvement of agriculture, made his Address as Chairman of the Sub-section a special plea for the recognition of this subject, and a subsequent Chairman, Major Craigie, used, I have been led to understand, all those arts of peaceful persuasion of which he is a master, in order to secure the formation of this Section. Other officers of the Sub-sections, too, have worked hard for this result, and to them those of us who are now assembled to take part in the first meeting of the new Section owe a debt of gratitude.

In view of the subjects which, in recent years, have engaged the attention of the Agricultural Sub-sections, it was suggested to me that for the Dundee meeting a paper dealing with some agricultural question of the past would be appropriate. As from my personal point of view this would have the advantage of causing me to renew acquaintance with treasured, but latterly somewhat neglected, old volumes which fill my study shelves, I readily accepted the suggestion. A subject from the past has for me the additional attraction that it relieves me altogether from a discussion of questions related to my daily work. A President of a Section is, indeed, expected to speak about his own work; but mine belongs to that category which many people seem anxious to learn about before it has been made public, and in which nobody is particularly interested after, in buff, or blue, or white garb, it has been issued by His Majesty's Stationery Office, and is purchasable at the modest figure which represents the cost of paper and printing.

With the view, then, of informing ourselves of certain phases of agricultural progress in the past, and at the same time gaining some inspiration for the future, I propose to invite your attention to the prototypes of Section M. When did the first associations for improving agriculture appear? What were the circumstances which led to their formation? What were their aims? What did they

accomplish? These are the questions which I shall try to answer, or, rather, to which I shall attempt to indicate the answers, for to deal with them adequately would occupy much more time than is at our disposal to-day

It is not inappropriate that the relation of societies and associations to agriculture should occupy our attention in this town of Dundee, for here, in 1796, there was published a work on agriculture by a prominent Forfarshire agriculturist, James Donaldson, in which a vigorous appeal was made for the establishment of societies so that a spirit of improvement might be aroused among farmers Donaldson, in referring to the Reports of the Board of Agriculture, then being issued, complained that it was quite impossible to reach the farmer by means of such expensive volumes He urged, therefore, the publication of a cheap journal, and with this the formation of county societies with the object of spreading far and wide the information of which Sir John Sinclair and Arthur Young had collected so large an amount Three years later, in May 1799, the Board, taking Donaldson's hint, addressed a circular letter to landowners on the subject, which resulted in the formation, between the beginning of the century and 1815, of a number of local associations for improving agriculture

I began the preparation of this Address with the intention of giving some account of the progress made in the end of the eighteenth and the beginning of the nineteenth centuries, when Sir John Sinclair and Arthur Young were so actively engaged in promoting agriculture But, as my notes progressed, I found that it would be necessary to limit my remarks to a period ending with the accession of George III. I will therefore ask you to follow me while I endeavour to trace the rise and progress of the Improver of Agriculture and the work of associations which, before the year 1760, prepared the foundation on which, in the second half of the eighteenth century, Sir John Sinclair and Arthur Young reared the superstructure of the first Board of Agriculture While this subject calls for no references to my official work, I may perhaps be permitted to claim that it is one on which I may appropriately address you, inasmuch as the functions of the old Board closely resembled those of that Division of the present Board of Agriculture and Fisheries with the supervision of which I am charged

Although Section M meets for the first time to-day, and though Sub-sections for agriculture belong to recent years, agriculture, on many occasions in the past, has occupied a place in the discussions of the British Association To one of the earliest meetings Justus von Liebig contributed a report on the state of organic chemistry which he subsequently republished under the title 'Chemistry in its Application to Agriculture and Physiology' In the dedication of this volume to the British Association occur these words 'One of the most remarkable features of modern times is the combination of large numbers of individuals representing the whole intelligence of nations for the express purpose of advancing Science by their united efforts, of learning its progress, and of communicating new discoveries'

I think that Liebig's statement, which had reference more especially to the sciences then occupying the attention of the members of the British Association, applies also to movements for promoting the study of agriculture I can find no evidence that societies for the advancement of agricultural knowledge existed among the ancients The question is, however, not one which I have investigated fully, and without further study I am not prepared to state definitely that such societies belong exclusively to modern times The old Scottish writer 'A Lover of his Country' states that 'the Propagation of this useful Science (agriculture) was the Care, as well as the first Rise of many considerable and famous Societies in *Athens*' and so it may have been that centuries before St Paul visited the Areopagus, the Athenians congregated on Mars Hill discussed questions of husbandry after the manner of Socrates, Critobulos, and Ischomachus in Xenophon's 'Œconomics' Indeed, if we reflect that Europe was backward among the continents in giving attention to husbandry, that 2,800 years before Christ an Emperor of China is said to have instituted a ceremony for the purpose of impressing on his subjects the importance and the dignity of agriculture; that the Egyptians had developed a Land of Goshen before the time of Joseph, that the trees in the 'paradises' of Persia were planted by those princes skilled in arboriculture who are praised by Socrates, and that the treatises of Mago, the 'Father of Husbandry,' were among the treasured possessions of which Carthage

was despoiled by her Roman conqueror, it does not seem improbable that associations for the advancement of agriculture may have existed in ancient times.

But if such associations did exist, they either neglected to appoint recorders or their records were among the many old writings on husbandry which are known to have been lost. It is certain that Columella, who in the first century of our era garnered the wisdom from all known works on agriculture, had never heard or read of associations for promoting agriculture. For in his First Book on Husbandry he laments the absence both of the means of instruction and of the desire for study among his fellow-countrymen, and, writing of agricultural education, he sorrowfully describes how in the case of other arts,[1] 'everyone sends for a person from the society and assembly of the wise to form his mind and instruct him in the precepts of virtue, but Husbandry alone, which, without all doubt, is next to, and as it were near akin to wisdom, is in want of both masters and scholars.' And he proceeds, 'For hitherto, I have not only heard that there are, but I have myself seen, schools of professors of Rhetoric, and as I have already said of Geometry and Music, or, which is more to be wondered at, academies for most contemptible vices, for delicately dressing and seasoning of victuals, for contriving and making up dainty and costly dishes for promoting gluttony and luxury; and I have also seen head-dressers and hair-trimmers; but, of Agriculture, I have never known any that professed themselves either teachers or students.'

These quotations, while they show that associations for the advancement of agriculture were unknown to Columella, also show the Roman writer to have been fired with that zeal for knowledge which possessed our own Improvers of Agriculture in the seventeenth and eighteenth centuries. Nor is it a difficult task to trace back to the ancients the 'Spirit of the Improver,' which appeared in England about the middle of the seventeenth century. The influence of the classical writers may indeed be traced in the second half of the sixteenth century, but at that period English agriculturists were impressed only by the practice of the ancients, as exemplified in the careful rural economy of Roman husbandmen, the knowledge, or science, of agriculture—on the importance of which several of the ancient writers have discoursed at length—did not attract Englishmen before Bacon's time.

Interest in the practice of improved husbandry was first aroused in England by the books of Fitzherbert. The extent to which this author stimulated agriculture may be inferred from the appreciation with which his works were received in his own day, and copied by others for a century. He himself does not appear to have been acquainted with the classical writers. He describes the English practices with which he was familiar, he quotes frequently from the Scriptures and refers to early religious works, but only in writing of animal diseases, when he cites the 'Sayinge of the Frenche man,' is there any indication that he was influenced by foreign authors. Fitzherbert's 'Boke of Husbandry' and 'Surueyenge,' while they are free from the direct influence of Roman writers, show us, nevertheless, that the English agriculture of his day owed much to Roman traditions. The careful business methods and accounting of the farm bailiffs of the Middle Ages, with which Thorold Rogers has acquainted us, were the methods which Fitzherbert learned and counselled, as they were the methods which Columella taught.

It was between 1523, when Fitzherbert's 'Boke of Husbandry' was first printed, and 1557, when Tusser published his 'Points of Good Husbandry,' that the classical writers began to exert a direct influence on English farming. In 1532[2] there appeared Xenophon's 'Treatise of Householde,' 'ryht counnyngly translated out of the Greke tonge into Englyshe by Gentian Hervet,' which at once became popular and ran through a number of editions. At least as early as 1542 editions of the works on agriculture and gardening of Cato, Varro,

[1] I quote from the edition published in 1745 by A. Millar, London.

[2] The earliest edition in the Cambridge University Library is dated 1537, but Dr Peter Giles informs me that the earliest copy in the British Museum is dated 1534, and that, according to the old Bodleian Catalogue, Oxford had a copy dated 1532. My own copy is a 1767 reprint which describes Hervet's translation (in 1537 bound in one volume with Fitzherbert's *Husbandry and Surveying*) as having been extremely popular.

Columella, and Palladius [1] were published in England, and they must certainly have been known to Tusser, for in his 'Five Hundred Points of Good Husbandry,' composed some years later, there is clear evidence of the influence of the writings of Xenophon and Columella. From the latter author Tusser adopts the method of a calendar, and he appears now and again to adapt Roman maxims to modern conditions. Thus in his calendar Columella says of March that it 'is the proper time to cleanse meadows, and to defend and secure them from cattle, in warm and dry places indeed that ought to be done even from the month of January,' and Tusser in his calendar for March rhymes:—

> 'Spare meadow at Gregorie Marshes at Pask
> For feare of drie Sommer no longer time ask
> Then hedge them and ditch them, bestow thereon pence,
> corne, meadow, and pasture aske alway good fence.'

It might be, of course, that in discussing the same subject, a subject moreover which does not admit of much difference of opinion, the similarity of the above-quoted passages is accidental, but many of Tusser's rhymes so closely follow Xenophon's 'Householde' and Columella's Eleventh Book that I am satisfied Tusser was familiar with both these ancient writers. Here, for example, from Tusser, is the charge concerning sick servants which Ischomachus gives to his young wife:—

> 'To Seruant in Sickness see nothing ye grutch,
> a thing of a trifle shell comfort him mutch.'

And here is a maxim for the housewife that Columella enforces:—

> 'The woman the name of a huswife doth win
> by keeping hir house and of dooings therein
> And she that with husband will quietly dwell
> must thinke on this lesson and follow it well.'

Until the dawn of the twentieth century no mere man would have been found to question the conclusion come to in the above verse, nevertheless, the emphasis on the 'quietly dwell' indicates that in this particular case the inspiration is derived from Columella rather than from Xenophon. For while the woman described by the Greek writer is likened to the queen bee, by the Roman there is much lamentation because of the emergence of the 'butterfly.' Columella refers to the diligent dames of ancient Rome who lived at home and studied to improve their husbands' estates, and contrasts them with their successors in the first century, who had become indolent, refused to make their own clothes, and spent their husbands' incomes on dress. He then remarks, 'Is it a wonder that these same ladies think themselves mightily burdened with the care of rural affairs, and esteem it a most sordid business to stay a few days in their country houses?'

Personal carefulness on the part of master and mistress was to the Roman the essence and the sign alike of good husbandry, by Tusser's rhymes this lesson was enforced at a time when an increase in the cost of living was attracting attention all over the country, his book went through a number of editions, and his pointed rhymes appear to have exercised a greater influence on the rural economy of the first half of the seventeenth century than the works of any other writer. Thus, for example, in Best's 'Farming Book,' written by a Yorkshire gentleman in 1641 for the guidance of his son, Tusser is frequently cited as an authority. But Best, though a classical scholar himself and probably acquainted with some of the ancient writers on husbandry, makes no reference to them, the Yorkshire squire apparently regarded the writings of Varro and Columella as being of no real use to a farmer.

It was, then, the practice of husbandry that engaged the English agriculturist's attention from the time of Walter de Henley to Thomas Tusser, and the purpose of my digression into domestic subjects is to show that when the ancient writers were rediscovered in the middle of the sixteenth century, it was not the frequent

[1] A translation of Palladius into English was made about 1420, but it was not discovered and published until within recent times.

references of Xenophon to the science of husbandry but his economic and moral teaching, not Columella's First Book, with its appeal for doctors and disciples who might apply themselves to the study of agriculture, but his Eleventh Book, with its calendar of operations and its directions for the ordering of the bailiff and the bailiff's wife, that attracted Tusser and his readers

The awakening of interest in husbandry was largely due to the rapid changes in the economic conditions of England which set in about Fitzherbert's time These changes we cannot now discuss, but their magnitude may be indicated by the rise in price of the single staple, wheat According to Thorold Rogers, the average price between 1400 and 1540 was 5*s* $11\frac{3}{4}$*d*, the decennial average for the last four decades being 5*s* $5\frac{1}{2}$*d*, 6*s* $8\frac{3}{4}$*d*, 7*s* 6*d* and 7*s* $8\frac{1}{2}$*d* Between 1541 and 1582 the average price was 13*s* $10\frac{1}{2}$*d*, and 16*s* 8*d* for the last twelve years of this period Between 1583 and 1642 the average price rose to 36*s* 9*d* In particular years high prices were reached, and in 1596 and 1597 Fleetwood chronicles prices of from 80*s* to 104*s* per quarter

The change in the cost of living directed men's attention to the husbandry and housewifery recommended by Fitzherbert and Tusser The smaller landowners, who could no longer afford to live on their rents, and who saw that yeomen and tenant farmers were prospering, turned their attention to farming, and agriculture became an important occupation of the educated classes

The yeoman and tenant farmer did not ask for text-books on agriculture, but the new agriculturists required information, and thus there arose at the end of the sixteenth century a great demand for books The booksellers were not slow to make provision for the demand, writers were secured, books were published, and of the more popular many editions were sold

Even such a ready writer and successful adapter of other men's books as Gervase Markham got more work than he could do His book on live-stock was bought up so freely that in 1617 he resolved to write no more on this subject, and the public demand was satisfied by the issue of reprints His 'Farewell to Husbandry,' too, was reprinted in many forms My copy, for example, is a fourth revision printed by William Wilson for John Harison in 1649, while the copy figured in MacDonald's 'Agricultural Writers' is also a fourth revision, with an almost identical title-page, but printed by Edward Griffin for John Harison in 1638

At the end of the sixteenth century the practice of Continental farming began to attract attention in England, and a further proof of the demand for information which then existed was the translation in 1600 of 'Maison Rustique,' a French work by two doctors of medicine, Charles Stevens and John Liebault This volume, in its English form known as the 'Countrie Farme,' contains seven books and nine hundred quarto pages It is intended to be a complete guide for residents in the country, and deals with everything that the landowner wants to know, from the care of his health to forecasting the weather The work is interesting in other ways than as an indication of the new appetite for books As in Heresbach's works, translated by Barnaby Googe in 1577, we find in the 'Countrie Farme' the acknowledged influence of the ancients Reference is made to the Greek writings of Hesiod, to Mago of Carthage, and to the high esteem in which the Latin works of Columella, Varro, and Cato were held, we are informed that French translations of the works of the three last-named were in existence in 1582

The English agriculturists of the sixteenth century went abroad for more than books Gerarde, who like others of his profession deserted medicine to the great advantage of botany, had obtained a number of foreign plants for his collections From the gardener, too, England learned of the skill of the Flemings, and would gladly have copied their practice But the Flemings were too busy to write books, so Englishmen went to see for themselves how and why they prospered

Sir Richard Weston, a Surrey landowner, who succeeded to his estates in 1613 and who had travelled in Brabant and Flanders, was the first English agriculturist to introduce practices approved on the Continent He grew turnips for feeding cows, a century before the time of Turnip Townshend, nearly three hundred years ago he was experimenting, as we are still doing, with clover seed grown in different countries; he had thirty to forty acres of clover sown with barley, and he was inveighing against the sophistication of

'outlandish' grass seeds and contriving plans for raising pure stocks at home in the approved fashion of to day

The importance of such crops as clover, lucerne, sainfoin, and turnips was quickly recognised, and agriculturists wished to hear and read more about the husbandry of the places from which they had come Information was supplied in the works of the alien writers Plattes and Hartlib; the latter especially, by his 'Legacie' and his 'Reformed Husbandman,' did much to popularise a knowledge of Continental farming and to suggest 'the errors, defects, and inconveniences of our English husbandry' Hartlib was a widely travelled man, and gave our Improvers many fresh ideas, among them a suggestion for a 'Colledge of Husbandry,' but we cannot claim him as an English agriculturist

It was not only from Brabant and Flanders that travellers brought to England information about foreign agriculture As one result of the development of commerce voyagers were introducing from distant countries such important plants as the potato and tobacco, and were exciting interest by their stories of foreign products. A desire to make experiments with these novelties was but natural, and experimental farming received a powerful impetus from the teachings of Francis Bacon, the first exponent of the inductive method Having, as he wrote, 'taken all knowledge to be my province,' Bacon was himself an amateur farmer, and if he was not a successful one he was at least intent upon introducing methods of 'industrious observation and grounded conclusions' It is to Bacon, I think, that Arthur Young alludes in a passage in which he describes a Lord Chancellor of England as having procured and read every published work on husbandry so that he might learn how to farm, and who, having met with ill-success, collected the offending books and lighted a bonfire! But let us not think lightly of the efforts of this distinguished amateur farmer The agricultural writers of the succeeding century, indeed, refer to the influence of Bacon in terms that suggest for Agricultural Science the origin of the phœnix We may, at least, agree that about the time of Bacon's bonfire this subject first began to attract the notice of scholars

In spite of the political troubles of the second quarter of the seventeenth century, agriculture continued to secure increased attention, for England had learned that in war or peace the food-supply must be cared for, and the importance of corn-growing increased with the rise in prices Thus when the Commonwealth was established everything favoured a forward movement At peace and able to return to country pursuits, the combatants, Cavaliers and Roundheads alike, became active improvers Engineer agriculturists, like Vermuyden, carried out great drainage-works Many estates had changed hands, and the new owners, not a few of whom, as Harte remarks, 'had risen from the plough,' were glad to return to it; others were amateur farmers intent on learning The books of the old and trusted writers, Fitzherbert and Tusser, had been followed by the works of such authors as Norden, Markham, Plattes, and Hartlib Bacon's teaching emphasised the need for further study and experiment Behind the political and economic changes were the powerful moral influences of the Puritan movement, it was at this time and under these conditions that the Spirit of the Improver, which had animated Columella, appeared among English agriculturists

The first practical farmer to plead the cause of the improvement of agriculture was Walter Blith, one of Cromwell's soldiers who is supposed to have been a Yorkshire landowner, but who for some years, at least, was stationed in Ireland To him may be attributed the first improvements in Irish farming Writing in 1770 Harte says: 'Ireland it must be confessed had a wretched method of husbandry and strong prejudices and beliefs in that method when Blythe alone (who then lived in Ireland) was sufficient to open men's eyes by his incomparable writings'

Blith was himself an ardent agriculturist, and prefaced his practical book, 'The English Improver Improved,' by seven epistles designed to attract the attention of all classes of his fellow-countrymen to agriculture. These epistles were addressed to 'The Lord Generall Cromwell,' the 'Industrious Reader,' the 'Nobility and Gentry,' the 'Honourable Society of the Houses of Court and Universities,' the 'Souldiery of these nations of England, Scotland, and Ireland,' the 'Husbandman, Farmer, or Tenant,' and to the 'Cottager, Labourer, or Meanest

Commoner.' With the 'Lord Generall' he pleaded for an Agricultural Holdings Act and the other legislative measures required by Improvers. To the 'Industrious Reader' he expounded the reasons for the methods of his book, and commented on the work of previous authors, commending Sir Francis Bacon's 'Naturall History' as 'worthy of high esteeme, it is full of Rarities and true Philosophy.' He exhorted the army to set themselves to the improvement of the land now that they have the 'goodness and welcomeness of a Calme after a storm.' But it is in the epistle to the 'Honourable Society of the Houses of the Court and Universities' that chief interest lies for us, for here we find an appeal for the systematic study of agriculture in words that recall the classical writers. Blith showed that agriculture required the close study of the learned, and that the societies (*i.e.*, the Colleges) of the Universities might if they wished do much for its advancement. He approaches them as a suppliant with no suggestion that they should abandon their 'sublimer Notions,' but with the hope that they may be induced to regard agriculture as a recreation, so that, as he says, 'you may step a little into the field and Country and cast away an hour or two upon this Subject at your leisure.' He adds, 'You that have the Theorick, may easiest discover the Mysteries of the Practick, and from you have I found most encouragement to this work, and seen most experiences of good husbandry than from any, and from you too I expect and waite for more discoveries of some thing I scarce know what to name it, which lies yet in obscurity, but I will call it the Improvement of the Improver.'

Were we not now concerned with the spirit rather than with the form of the improvement, an interesting parallel might be drawn between the topics which Blith considers of greatest importance and those which to-day are engaging attention. In his epistle to the Society, for example, there is an appeal to the learned to give their attention to Applied Science. Discussing the progress of the Dutch, Blith deplores that policy which Englishmen afterwards termed *laisser faire*. He says, 'Our niceness in not nursing the fruits of our own bowells hath given them the opportunity to Improve our native commodities to the advance of their Manufacturidge to our shame, their praise', then addressing members of the Universities he adds, 'I speak to wise men whom I would have more publique men. . . . Let me entreat you for the Peoples and your own posterity sake . . . put your shoulders to the work, greater things remaine and larger Improvements are yet to be discovered.'

The earnest advocacy of Blith, the Essays of 'my good friend Mr. Samuell Hartleps,' and the energy of landowners like Sir Richard Weston led to a demand for the records of experiments, and in 1658 there was issued the first series of abstracts of agricultural experiments with which I am acquainted, under the title 'Adam out of Eden.' The experiments recorded by the author, Ad. Speed, are of considerable interest, but I mention him for another reason. He appears to have made a living by propounding improvements of an imaginary character. He wrote tracts for noblemen and others, containing estimates of the profits to be gained by adopting new methods. Blith scathingly refers to him as 'Mr. Speed that superlative Improver,' and remarks that so long as his books were private 'I could bear it, and suffer wiser than myself to bee fooled because I was not wise enough as to beware of him, but now that they come to be sold in the Stationers' Shops, and spread abroad the country, to deceive, and beguile the Nation, I cannot forbear.' This was written in 1652; as my edition of 'Adam out of Eden' is dated 1659, it is clear that the nation continued to be 'beguiled' for a considerable period by this particular Adam, the forerunner of a numerous family. Whenever there is a revival of interest in agriculture he flourishes, the new manure, the ravaging insect, the blighting fungus, all serve to bring 'Adam out of Eden,' and so long as an interested and gullible public exists 'that superlative Improver Mr. Speed' will be found among us. The pamphlet and the stationers' shop have become antiquated, the Adam of to-day has other methods, which I will not venture to particularise. After all, it is a healthy sign. It is only when the public thirst is deep that Adam gets his chance, and like Blith we must resign ourselves now and again to 'bee fooled,' for is it not one of the methods by which the Improver is improved?

Walter Blith's appeal for the assistance of the learned did not long remain unanswered. At the time his 'English Improver Improved' was published a

society of scientific men had already been formed in London, and ten years later this society first received the name Royal Society, at the suggestion of John Evelyn On October 15, 1662, Evelyn's 'Discourse on Forest Trees' was presented to the Society. Five years later, when the 'Sylva' was published, the author in the preface tells us that the Royal Society was then doing much for husbandry. Evelyn records his own experience in studying agriculture and forestry, how he had read all the old authors and got but little good from his studies, and he congratulates his countrymen that 'the *World* is now advis'd and (blessed be *God*) redeemed from that base and servile submission of our noblest *Faculties* to their blind *Traditions*' Again, referring to the absence of a 'compleat *System of Agriculture*, which as yet seems a *desiderata*,' he says 'It is (I assure you) what is one of the Principal *Designs* of the Royal Society, not in this Particular only, but through all the Liberal and more useful *Arts*, and for which (in the estimation of all equal *Judges*) it will merit the greatest of *Encouragements*; that so, at last, what the learned *Columella* has wittily reproach'd, and complained of, as a defect in that *Age* of *his*, concerning *Agriculture* in general, and is applicable *here*, may attain its desired *Remedy* and *Consummation* in *This* of *Ours*' He then quotes Columella's remarks about the Schools of Rhetoric, Geometry, and Music, and the absence of agricultural professors and scholars, which I have already read

John Evelyn was one of the prominent members of the Royal Society, and he seems to have taken a leading part in defending it against the attacks to which, in the first years of its existence, it was subjected With much satisfaction he points out, in dedicating the second edition of the 'Sylva' to King Charles II, that his essay and the work of the Royal Society have in the past eight years resulted in the planting of over two million timber-trees, and he adds that he has preserved the testimonials he has received with the more care '*because they are* Testimonials *from so many* honourable *Persons*, *of the* Benefit *they have receiv'd from the* Endeavours *of the* Royal Society, *which now adayes passes through so many* Censures'

With the exception of the 'Societies of Learning and Gallantry' of the 'Houses of Court and Universities' addressed by Blith, the Royal Society is the earliest to which any influence on agriculture may be traced, and it is certainly the first society which definitely included the improvement of agriculture as coming within its scope It appears to have depended in no small degree for its early successes on the public interest aroused by the writings of Evelyn and Houghton, and there is evidence that the Society gave much attention to agriculture during the second half of the seventeenth century, and that its patronage was much valued The immediate influence of the Royal Society may be traced in Worlidge's '*Systema Agriculturæ*' In my edition (the third, 1681), Worlidge makes a strong plea for improving agriculture, he quotes at length from ancient writers to prove the esteem in which the art was held by them, and then says. '*Also a most evident demonstration and sure Argument of the Utility, Pleasure and Excellency of this Branch of Natural Philosophy, is the principal care the* Royal *and* Most Illustrious Society *take for the advancement thereof, and for the discovery of its choicest and rarest secrets*' He also refers with special approbation to the work of Evelyn, not only in promoting forestry, but in improving the making of '*that incomparable Liquor* Cider'

Evelyn's 'Pomona,' in which he discourses of fruit trees and cider, gives an interesting glimpse of some of the early activities of the Royal Society, for the work itself is based chiefly on contributions by members of the Society to its '*well furnish'd Registers, and* Cimelia' Evelyn is careful to point out that these contributions were original papers and that it was not the design of the Society to 'accumulate repetitions where they can be avoided', these new observations being in the Society's esteem '*and according to my Lord* Bacon's' preferable even when '*rude and imperfect* draughts' than commonplaces '*adorn'd with more* pomp' Evelyn himself was not practically acquainted with cider-making, and his own interest in the subject, like that of the majority of his fellow-members, was Baconian—*i e*, it consisted in a search for 'grounded conclusions and profitable inventions and discoveries.' Possibly, too, the badness of the French wines of the period had some share in directing the attention of the Fellows of the Royal Society to cider, for as early as January 28, 1662, they listened to a discourse on the Adulteration of Wine, by Dr Charleton, which so

stirred Evelyn that he wrote '*To sum up all If* Health *be more precious than* Opinion, *I wish our Admirers of* Wines, *to the prejudice of* Cider, beheld but the Cheat themselves, *the* Sophistications, Transformations, Transmutations, Adulterations, Bastardizings, Brewings, Trickings, *not to say even* Arsenical Compassings, *of this Sophisticated* God *they adore, and that they had as true an* Inspection *into those* Arcana Lucifera, *which the* Priests *of his* Temples (*our* Vintners *in their* Taverns) *do practice, and then let them drink freely that will.* Give me good *Cider*' And so apparently said some of his fellows, for the Society's curator, the 'ingenious Mr Hooke,' introduced a new cider-press, and Sir Paul Neile, that 'most worthy member' Di Beale of Yeovil, and others, were commanded to discourse on the manufacture of varieties of this pure beverage, and to recommend such brews as Pepin-cider adapted for splenetic gentlemen, and Gennet-moyl suited to the palates of ladies

In other ways the members of the Royal Society encouraged one another in making improvements, thus when in 1666 Evelyn's 'worthy friend' Mr Hake went on a journey, he returned carrying with him—for eight hundred miles—some grafts for Evelyn, together with a 'taste of the most superlative perry the world certainly produces' It was by means such as these, and by a policy which approved 'plainness and usefulness' rather than 'niceness and curiosity' that the newly formed Royal Society commended itself to the country

It is indeed probable that agricultural questions occupied much more of the attention of the Royal Society in the earlier years of its existence than the printed records suggest, we are told, for example, by the Scottish Improver, 'A Lover of his Country,' that one of its most illustrious members, Sir Robert Boyle, was an enthusiastic agriculturist, he says 'I had the Honour to be known to that excellent Person and oft in his Company He was the greatest Lover of Agriculture I ever knew, and I wonder he never wrote of it I heard him say, it was a Pity there was not Seminaries of that, the most useful, and except Pasturage, the most ancient of all Sciences'

Not only were agriculturists attracted by the practical investigations of the Royal Society, but impressed by the value of its methods and organisation, and Worlidge suggests that nothing would more conduce to improving agriculture than the constitution of subordinate Provincial Societies '*whose principal care and office might be to collect all such Observations, Experiments, and Improvements they find within their Province which of necessity must abundantly improve* Science *and* Art *and advance* Agriculture *and the* Manufactures'

The proposal made by Worlidge was unheeded at the time, for not until nearly a century after his suggestion was made did English Agricultural Societies begin to appear A retrograde movement set in soon after the Restoration, and although the Government sought to foster improvements and passed several Acts with the object of stimulating farming, Harte tells us that a 'total change of things, as well as the very cast and manner of thinking, joined with immoral dissipation, and a false aversion to what had been the object and care of mean despised persons, soon brought the culture of the earth into disrepute with the nobility and gentry'

An insight into the conditions of the last quarter of the seventeenth century and the first quarter of the eighteenth is given us by Lisle, who wrote the Introduction to his 'Observations on Husbandry' in 1713 He begins by remarking that it is one of the misfortunes of the age that it lacks honourable conceptions of a country life, he draws attention to the fact that in the decadent days of Rome luxury increased and husbandry was neglected He calls on the landowner to look round him and see how many fine estates are daily mortgaged or sold, 'and how many antient and noble families destroyed by the pernicious and almost epidemic turn to idleness and extravagance' He discusses at length the advantages of an agricultural career and recommends it as a profession for the eldest sons of gentlemen, who might regard it as 'a school of profit and education; whereas,' he continues, 'it is rather looked on as a purgatory for the disobedient, a scene of punishment, to which a son, who answers not his father's expectations, is to be abandoned; or a condition of life of which none would make choice, but such whom fortune has not in other respects favoured. If the country gentlemen therefore frequently consist of persons who are either rusticated by their parents in anger, or who, making a virtue of necessity, settle on their estates with aversion or indifference, it is no wonder the comedians exhibit them on our

stage in so despicable and ridiculous a figure; but this is the fault of the persons and not of the art. Were they properly initiated in the study of Agriculture, and pursued it as they ought, it would be so far from excluding them from useful knowledge, and bringing them into contempt, that I may venture to assert, they would find it the best school of education, and the fittest to prepare them for the service of their country in the two houses of parliament of Great Britain.'

Such were the dispiriting social conditions with which the successors of Evelyn in the Royal Society had to contend The agricultural experiments of the Society therefore attracted but little attention outside the ranks of the curious Houghton, a contemporary of Evelyn's, started a periodical publication, 'Houghton's Letters,' but it soon ceased A generation later, and about the period to which Lisle refers in the above quotation, a work on husbandry was written by a Fellow, John Mortimer It is dedicated to the Society, 'to whose encouragement, inquiries, and direction it owes its birth' Special thanks are given to another Fellow, Dr Sloane, who assisted the author, and 'has greatly contributed to the advancement of useful knowledge'

Testimony to the activity of the Royal Society at this period is also to be found in a work on 'Curiosities of Nature and Art in Agriculture and Gardening,' a translation from the French of the Abbot de Vallemont by Bishop William Fleetwood, published anonymously in 1707, this work contains the passage 'The Royal Society of *England* who are so zealous for the Perfection of Agriculture and Gardening, have apply'd themselves with great Care to find out the true way to make Salt-petre, which they likewise allow to be the chief Promoter of the Vegetation of Plants'

About this time botanical questions of much interest to agriculturists were occupying the attention of the Royal Society Robert Ball and Samuel Moreland were investigating reproduction in plants, and a few years later Richard Bradley, another Fellow, Professor of Botany at Cambridge, but more of an agriculturist than a botanist, was explaining how, by cross-breeding, 'such rare kinds of plants as have not yet been heard of' may be produced He refers specifically to a cross between a carnation and a sweet-william, but by inference to Burgoyne's Fife and the other things 'not yet heard of,' that are associated with agriculture and botany in the Cambridge of to-day

Various causes, among which the influence of Fellows of the Royal Society must be given an important place, led the landowners and the educated classes of England again to turn their attention to agriculture about the beginning of George II's reign The revival was associated with and followed, as it has in recent time, a development in gardening William and Mary were patrons of horticulture, they greatly improved the Royal Gardens, and the nobility, in imitation, laid out parks and *parterres* This demand gave opportunity to the professional gardener, and the garden-designer and nurseryman started business. It likewise gave authors their opportunity, and that it was well taken advantage of is proved by the popularity of Miller's Gardeners' Dictionary written by the Gardener of the Botanic Gardens at Chelsea, and dedicated to Sir Hans Sloane, President, and to the Fellows of the Royal Society

A second writer on gardening of this period, the Reverend John Laurence, of Bishop Weremouth, Durham, may be mentioned, for he was also one of the chief agricultural writers of the first half of the eighteenth century. In 1726 he published a large folio work entitled 'A New System of Agriculture' This book marks the time when what the author calls the 'Spirit of Gardening' appeared, and it proves that gardening was very popular with the landed and educated classes for some years before the revival in agriculture began Laurence refers, as Lisle did a few years before, to the lack of interest in husbandry, and remarks . 'If Gentlemen could persuade themselves to cast their Estates into Beauty and Order, they would quickly experience it the noblest Exercise and greatest Delight.' Every age, he remarks, has its own amusements, 'This Age, it is plain, seems to taste and relish everything new on the Subject of vegetable Nature' He attributes the 'relish' not merely to progress in the art of gardening, fostered by nobles and statesmen, but to the Royal Society—of whom he says that their Philosophical Transactions 'are standing Memoirs of the Zeal and Activity of many Persons of Quality and Learning,' whose 'Discourses and Experiments' have 'advanced much Light in the Art of Husbandry.' Incidentally he refers to the condition of the North of England, and says that the county of Durham

may properly be termed the Garden of the North, such are the possibilities of improvement afforded by its soil and situation and the 'hasty Diligence of a wise and polite People.' Laurence's work was intended to place before these northern agriculturists an account of all the experiments that had been made in husbandry and especially to set forth in plain language the information published by the Royal Society. He appeals to his brethren in the Church to exert themselves in the cultivation of their glebes, which would give them both the 'Relaxation and Refreshment they require,' and he says, 'I should think myself extremely happy if I could be instrumental in reviving among Gentlemen whose affairs do not oblige them to spend a great part of their Year in *London*, a Spirit of improving their Estates and imploying their Time in making Experiments, which cannot be expected from the farmer.'

Although for seventy years after its formation, and throughout a period during which agriculture was neglected by the landed classes, the Royal Society did much to keep alive the Spirit of the Improver, the unfortunate apathy of the agriculturist prevented that progress which appeared to be imminent when John Evelyn wrote his 'Pomona' It was not possible for a learned society in London to investigate agricultural questions in the absence of the scientific agriculturist himself, subjects of agricultural interest were therefore discussed chiefly from a theoretical standpoint, and, neglecting the teachings of Bacon and the example of Evelyn, there arose that use of the deductive method which in the past two centuries has done so much to hinder the progress of agricultural science

The first to show up the fallacy of the deductive method in studying this subject was Jethro Tull, who, though he himself fell into the errors which he condemned, was, in his understanding of the true relationships of science and practice, far ahead of any of his contemporaries A lawyer by training, he probably took to agriculture because of his poor health He worked at it for twenty years before he was induced to set out his views in writing, and it was years after he began farming before he read anything on the subject Dissatisfied with the practice of his times he set himself to reason out new methods and to make experiments He got suggestions from foreign travel, he tells us, for example, that the first hint of the value of horse-hoeing husbandry was derived from the ploughed vineyards of France, but he was careful to submit his ideas to the test of experiment before he adopted them in farm practice He was not a Fellow of the Royal Society He lived a lonely life, and until the fame of his farming spread abroad and he published his 'Horse-hoeing Husbandry,' in 1730-31, he appears to have devoted himself entirely to experiments in farming The appearance of his book occasioned much correspondence, and thereafter he made himself acquainted with both the ancient and modern writers on husbandry, and used his knowledge to good effect in his arguments with the writers whom he terms collectively *Equivocus* His temper, which, if one may judge from his references to his labourers, was far from serene, was much tried by his controversies with *Equivocus*, and his criticisms of the writers and scientific men of the preceding half-century are severe He remarks, for example, on the superficial knowledge of agriculture shown by 'Mr Laurence, a divine, Mr Bradley, an academic, Dr Woodward, a Physician, Mr Houghton, an Apothecary, these for want of practice could not have the true theory, and the writers who are acquainted with the common practice, as Mr Mortimer (whether for want of leisure, or not being qualified, I do not know) have said very little of any theory '

Tull himself, a thoroughly experienced, practical farmer, whose successful methods had drawn widespread attention to his Berkshire farm, showed no hesitation in setting out his own views on roots, leaves, the pasture of plants, and other scientific subjects then engaging attention His remarks were based on original observations, and it is clear that he did not merely copy opinions from scientific treatises He freely criticised the writings of others, even 'Mr Boyle' and that 'miracle of a man Sir Isaac Newton' are severely handled by this critical farmer, and in a characteristic sentence he remarks 'From Sir Isaac's transmutation arguments we may learn that a man never ought to depend entirely upon his own for support of his own hypothesis' An admirable sentiment which I am afraid that Tull himself, and many another agriculturist since his time, failed to lay to heart When we remember how meagre were Tull's opportunities for study, that he lived a retired life in the country, that he had long abandoned letters for practical farming and only began to read the works of others

late in life, if, further, we remember that his health was bad, and that his appliances for scientific study were indifferent—'my microscope, indeed, is but a very ordinary one,' he writes—we must give him a foremost place among the scientific agriculturists, not only of the eighteenth century, but of all time. His wide knowledge and keen reasoning place his 'Horse-hoeing Husbandry' in a class by itself among the works of the early Improvers

Jethro Tull's great work was published two generations after Walter Blith first endeavoured to awaken the Spirit of the Improver in English farmers Throughout this period not much progress had been made, but a change was at hand When in 1730 Turnip Townshend left politics and went down to Norfolk to farm his estates, the tide had turned, and henceforward throughout the eighteenth century there was a rapid improvement in the practice of English agriculture Of these developments no small share may be attributed to the influence exercised by the Royal Society during the first seventy years of its existence

The agriculture of Scotland had not shared in the revival due to the work and writings of the English Improvers, and was in a very backward state in the middle of the seventeenth century Its condition is indicated by John Ray, who in 1661, some months before the Royal Society received its charter, set out from Cambridge to spend the Long Vacation in a Scottish tour He crossed the Tweed on August 16, and proceeded from Berwick, *via* Dunbar, to Edinburgh His first day's Journal gives us his impressions of what is now, and probably was then, one of the foremost agricultural districts in Scotland 'The ground in the valleys and plains bears good corn,' he says, but 'the people seem to be very lazy, at least the men' Scottish women, he writes, 'are not very cleanly in their houses, and but sluttish in dressing their meat' 'They have neither good bread, cheese, or drink They cannot make them, nor will they learn Their butter is indifferent, and one would wonder how they contrive to make it so bad'

There is evidence in the Journal that this rude fare disagreed with the traveller, who had but recently quitted Trinity 'high table,' and he is unduly severe on the people of the Lothians He draws attention, for example, to the plainness of the Scottish women and the vanity of the men, he criticises Edinburgh, and having studied its architecture he remarks on the College that 'the building of it is mean and of no great capacity, in both comparable to Caius College' Surely a superfluous comment in the Journal of a Scholar of St Catherine's and a Fellow of Trinity!

Ray's speech appears to have been as unguarded as his Journal, for he records that 'the Scots cannot endure to hear their country or their countrymen spoken against,' and it is indeed a fortunate thing that he did not seek to cross the Tay It would have gone ill with him in 1661 had he ventured to criticise the Highlanders or their food and drink English Science would, I fear, have suffered an irreparable loss, and there might have been no sufficient reason for that Cambridge Club whose members engage at festive gatherings to prevent the association of the name of Ray with indifferent viands

Agricultural affairs in Scotland became worse instead of better after Ray's visit, for a series of disastrous seasons set in as the century drew to a close In August 1694 we are told that 'a cold east wind accompanied by a dense sulphurous fog passed over the country, and the half-filled corn was struck down with mildew' So bad was the harvest that Hugh Miller tells of the children of a Cromarty farmer who spent the whole winter trying to pick out seed corn from the blighted crop In the following year summer and winter were alike tempestuous, and thereafter for five seasons there was scarcity, amounting in some districts to famine By 1701, when the climate began to improve, much land had gone out of cultivation Landowners could not get tenants to take vacant farms, and the outlook was of the gloomiest But a change was at hand, and at the time when Lisle and Laurence were deploring the lack of interest which English gentlemen manifested in rural economy, Scotland was beginning those improvements which in a century made Scottish agriculture and gardening the best in Europe It is indeed a remarkable circumstance that four generations after John Ray recorded his impressions of this lazy, backward nation, we should

find another member of the Cambridge Science School, Professor Martyn, taking some pains to prove that Philip Miller of Chelsea never saw Scotland. Miller was so great a gardener, Martyn remarks, that it was generally supposed he must have been a Scotchman, but it was a satisfaction to the Cambridge people of 1800 to know that this distinguished man (whose name and ancestry had then a local interest, for his son was first Curator of the Botanic Garden) had won his pre-eminent place in the gardening world on a purely English ancestry. I am not satisfied that Martyn was right, but in view of the manner in which the Spirit of the Improver was conveyed to Scotland, it would be ungracious to argue the point

The North Country saying 'the Gordons hae the guidin' o't' applies to agriculture as to much else in Scottish history. In 1706 Lord Huntly married the daughter of the soldier Earl of Peterborough, himself a notable Improver Lady Huntly (afterwards that Duchess of Gordon who is extolled by 'A Lover of his Country') found the north-east of Scotland in the miserable condition in which 'King William's dark years' had left it As late as 1709 many farms north of the Grampians were lying waste, the country was depopulated, and the state of the labouring poor was wretched in the extreme. Lady Huntly sent to England for ploughs and ploughmen and taught her neighbours the methods of improved husbandry Three North Country lairds, stimulated by her example, forsook politics and fighting for draining, planting, and experimenting with French grasses Among the three was Sir William Gordon of Invergordon, who began those improvements in Easter Ross which have converted the shores of the Cromarty Firth into one of the choicest agricultural tracts of Britain It was to share in the improving of this district that my own great-grandfather, later in the century, deserted Teesdale for the parish of Cromarty Thus the work of this first group of Scottish Improvers has for me a very direct interest

Just as in England a revival of agriculture occurred after the Civil War, so in Scotland the disturbances of 1715 were followed by important developments After the Union Scotchmen in increasing numbers took the high road to London, and at first with much less profit to themselves than those acquainted with the Scot in modern times might suppose As a result of social intercourse the upper classes began to copy the manners and customs of their rich English neighbours, and prices and the cost of living rose rapidly These economic changes, as in England a century before, turned the attention of landowners to the improvement of their estates, but as the Scottish laird of the beginning of the eighteenth century did not take readily to farming, a few of the more enlightened men among them saw that if improvements were to be made special measures were necessary. Impressed by the usefulness of the Royal Society, these reformers conceived the idea of establishing an Agricultural Society in Scotland This Society, which met for the first time in Edinburgh on June 8, 1723, and adopted the name of 'The Honourable the Society of Improvers in the Knowledge of Agriculture in Scotland,' was the first association to be formed for the express purpose of promoting agriculture Some account of its work is given in its 'Transactions' published twenty years later, but for a contemporary view of the problems which engaged the Society's attention we must go to a book published in Edinburgh in 1729 under the title of 'An Essay on Ways and Means for Inclosing, Fallowing, Planting, &c, Scotland, and that in Sixteen Years at farthest, by a Lover of his Country'

Of all old books on agriculture this is, to me, the most interesting The anonymous writer is believed to have been Brigadier-General Mackintosh of Borlum, one of the Rebel Leaders of 1715, who fell into the hands of the English at Preston, was imprisoned in Newgate, and sentenced to death But this Highlander was not to be held by English gaolers With some of his comrades he overpowered the prison guard and made good his escape The Essay was written, its author informs us, in 'my Hermitage'—supposed to have been a cell in Edinburgh Castle—and the writer remarks that he can give no better reason for his work '*than other* Enthusiasts *do, the Spirit* moves me'

Assuming 'A Lover of his Country' to have indeed been Mackintosh of Borlum, the prisoner employed his enforced leisure to great advantage He displays more familiarity with the classical authors than any of his predecessors, or for that matter than any of his successors, except Harte and Adam Dickson, and he had obviously studied all the more important works published in England

in the previous century He argues that since the Union, Scotland had not made progress, and that, while extravagance had spread and necessaries greatly increased in cost, no attempt had been made to learn good rural economy from the English He points out that until they improve their estates Scottish lairds cannot hope to emulate English landowners He counsels fallowing and inclosing, and recommends that skilled English labourers should be brought to teach English methods He indicates where the best workmen might be obtained Men from Devonshire for denshiring (paring and burning), men from Cambridgeshire for draining, men from Hertfordshire for ploughing, from Hereford for fruit planting, and from Shropshire for hedging He estimates that six hundred and forty men would be required for Scotland A 'regimental number,' he facetiously remarks, but a welcome regiment, for they would be armed only with spade and shovel! He would apportion a group of these men to every county in Scotland and place them under the guidance of County Supervisors 'And if I might have my wish,' he says, 'we should not go on by Halfs, and all *Europe* should be quickly disabused of the Reproach they load us with of *Idleness* and *Poverty*' In another passage he prophesies that '*Scotland* from one of the poorest, ughest, and most barren Countries of *Europe*, is, in a very few Years, become one of the richest, most beautiful and fertile Nations of it,' and who would now assert that the old rebel's prophecy has not been fulfilled?

Other objects requiring the attention of the Scottish Improver of 1729 were Land Tenure and Education Our author urges upon landowners the folly of a system of tenure which demands services from their tenants, and which affords the occupiers no incentive to improve their farms, and he advocates leases not only in the interests of the lairds themselves but in justice to the farmers

Mackintosh was an enthusiastic educational reformer, he animadverts on the unsuitable instruction offered in rural schools and explains how easily it might be improved Their Scottish schoolmasters knew Latin, why should they not translate passages from Varro, Columella, and other writers which boys might read? For the use of Charity Schools in remote parts the 'learned Mr *Ruddiman*' should be employed 'to translate and compendize' the works of Cato, Palladius, and others Why, he asks, should not one day a week be set aside for the discussion of agricultural subjects, so that country boys might 'dispute on points of Husbandry or breeding or fattening Cattle'? And why should those advanced pupils, who read Greek and Latin authors, have unsuitable text-books placed in their hands? Might not the chaste Hesiod and the useful Varro supplant such works as those of Sappho and Ovid? And why send so many dunces to the university? Let able lads go there by all means, but for the sake of fashion why spend the family income on educating one son at college and neglecting the others? From the school 'A Lover of his Country' turns to the kirk Much might be done if ministers fallowed or enclosed their glebes, and used their pulpits to enforce lessons of thrift and honest dealing Then, like Blith, he appeals to the universities 'And certainly,' he says, 'the learned Masters of our Universities are too well acquainted with the Ancients not to know that Agriculture was the first Care of all Legislatures', and he continues 'Natural Philosophy was acquired and attained to by those that laboured the Ground and sowed Seeds, saw their different Ways of Propagation, planted and transplanted Trees, Herbs, Roots, found what ground produced this best, what that, and left their well demonstrated experiments to their sons and posterity, they were the very first Philosophers To be sure Natural Philosophy was the first, and the sagacious Husbandman the first Philosopher, as the wandering Star-gazing Shepherd or Herdsman was the first Astronomer'

There is much else in this essay on 'Ways and Means' to which attention might be directed, but my immediate object is to indicate the nature of the questions that stirred the early Scottish Improvers to take action, and having done this I must pass on to notice the work of the Honourable the Society of Improvers in the Knowledge of Agriculture

As already mentioned, the Society of Improvers was constituted at a meeting held on June 8, 1723 At subsequent meetings in the same summer rules were drafted and the Society began its useful career at once A Council of twenty-five members was elected, the Council was divided up into sub-committees, each of which was charged with the care of a special branch of agriculture; the rules set out that the members of committees were to 'chuse different subjects in

Agriculture and mark down their thoughts thereon in writing ' They were also to correspond with the most intelligent agriculturists all over the country and to endeavour to get small local societies formed The chief duty of each sub-committee was, however, to give advice on the means of carrying out improvements Members were asked to send in an exact statement of their difficulties, and answers were forwarded by the Society If the suggestions proved useful, the recipient of advice was expected to report the result for the benefit of his fellow members

The volume of ' Select Transactions,' published in 1743, contains a number of specimens of the questions sent in and the answers supplied Such subjects as the draining of boggy land, the use of marl and lime, the effects of seaweed as manure, the cultivation of potatoes, hops, sainfoin, and flax, the feeding of cattle and the employment of steeps for corn were dealt with Most of the correspondence is with Scotchmen, but occasionally letters from others occur, including an interesting communication from Jethro Tull in which he says that ' twenty years ago there was much the same way of tillage in England as is now in Scotland, but it has since been exploded by experience, and the farmers have enriched both the land and themselves by plowing it more than they were wont ' Directions for lime-burning are contributed by Mr Lummis, ' who came from England and made the Rotheran Plough ' The ' Transactions ' have an advertisement of this plough, from which it appears that the Earl of Stair had sent one of his men to be taught by ' the best Plough and Wheel Carriage wrights in England,' and that Rotheran ploughs of very superior workmanship were being made at Newliston, West Lothian The Earl of Stair further laid agriculturists under obligation by introducing turnips, cabbages, and carrots as field crops, and he bred very good Galloway cattle Another notable man among these early improvers was the Earl of Islay, who gave special attention to the cultivation of peaty soils and succeeded in producing good corn and grass on land previously thought to be of little value He also planted extensively, and, according to Maxwell, introduced the larch, among other trees, to Scottish foresters

The Society did not confine its attention exclusively to agriculture It noted a natural connection between the agricultural and fishing industries, and did much to promote the latter, thus establishing an early precedent for the association of agriculture with fisheries for administrative purposes Manufactures too were encouraged, and in this connection there stands out the name of the Duke of Hamilton, who moved the following ' Overture ' ' That all of you and all under your Influence, should, for Examples to others, buy no foreign Linen for Shirting, Bed-linen, or any other Household furniture, and that you should propagate to the utmost of your power the wearing of home-made stamped Linen ' The consequence, we are informed, was that ' even at Publick Assemblies of Persons of the greatest Distinction, the whole Company appeared dressed in Linen of our own Manufacture ' The Duke's success with linen led him next to propose a resolution against the drinking of foreign spirits, so that the great sum annually sent to France for brandy might be kept at home ! The consequences were not so immediately noticeable as in the case of linen, for the local records of the east of Scotland show that the smuggling of French brandy was a very profitable trade throughout the eighteenth century It is, however, the case that at a later date the Duke's advice was followed, for not only linen but liquor of native manufacture came to be appreciated, ' even at Publick Assemblies of persons of the greatest Distinction ' , at assemblies, moreover, on both sides of the Tweed !

As the Fellows of the Royal Society had interested themselves in cider, so the Honourable Society of Improvers selected whisky for their care, and a good deal of attention was given to improvements in distilling Their correspondence shows that Scottish progress in this art was mainly attributed by them to Mr Henricus Van Wyngaerden, a Dutchman who settled in Edinburgh about 1730, and ' followed the distilling business with success and a fair character ', but here I question if the Society are altogether just to the enterprise of the father of one of their own most prominent members, Duncan Forbes of Culloden About 1670 John Forbes, a staunch Presbyterian, who owned an estate in the parish of Ferintosh, withstood Charles and James, and suffered for conscience sake When William came to the throne, John's son Duncan (father of the Society's member) claimed compensation from the Scottish Parliament His claim to compensation was

proved, but Parliament, having no money wherewith to pay, granted him permission to distil all the grain of Ferintosh at a nominal duty Thus, says John Hill Burton, Ferintosh became 'illustrious as the head-quarters of the distilling of whisky,' and he adds, 'so short-sighted is man, the efforts of the "merry monarch" to subdue the spirit of the stubborn Presbyterian became the source of conviviality for generations after he and his roystering companions were in their graves' To Duncan Forbes and Ferintosh rather than to the Duke of Hamilton or Mr Henricus Van Wyngaerden may be attributed the wide advertisement of native liquor and the gradual displacement of French brandy

During the twenty-two years of its existence the Honourable Society of Improvers became a powerful and important body Its influence, it should be noted, was obtained by educational methods, for its funds were small, it had no State subsidy as had the Irish Society, it offered no premiums, but it drew together in the cause of agricultural improvement many of the most prominent Scotchmen of the period, and it undoubtedly laid the foundations of that successful agriculture for which Scotland has ever since been noted In 1743 the Society had 299 members, and an examination of the list reveals many well-known names representing all sections of the educated classes of Scotland, with the notable exception of the clergy The great territorial houses were represented by the Dukes of Athole, Hamilton, and Perth, the Earls of Breadalbane, Hopetoun, Stair, and others, politics by Duncan Forbes of Culloden and his restless neighbour Simon of the '45, the College of Justice, the Bar, Writers to the Signet, the University of Edinburgh, and the Medical profession by Bethunes, Campbells, Dalrymples, Erskines, Fergusons, Gordons, and many another well-known Scottish name A link with the Board of Agriculture and Fisheries of to-day existed in Sir John Anstruther of Anstruther, and of another member, Alexander Brodie of Brodie, Lord Lyon, I have been frequently reminded in preparing this Address, for my copy of 'Columella' bears his bookplate

But of all the members, those who best deserve our notice are Thomas Hope of Rankeilor, President, and Robert Maxwell of Arkland, editor of the 'Transactions' Mackintosh refers to Hope as a man who had taught improved agriculture to hundreds of his fellow-countrymen He studied the subject not only in England, but in France, Flanders, Holland, and other Continental countries, and Maxwell says of him 'that it has been much owing to *Mr Hope of Rankeilor* your Preses, that this Society was entered into and that the Spirit of it rose so high,' and adds that he 'has been instructing others in the Knowledge of it and been preaching up the publick and private Advantages arising from it for a continued Tract of more than Twenty Years' Time' Of the spirit which animated Robert Maxwell himself we have ample evidence in the Dedication of the 'Select Transactions' Reviewing what has been done by the Society and considering that which might still be done, Maxwell writes, 'since the Case stands thus, how much doth it concern the Publick and every Individual that Agriculture be encouraged and that the *Knowledge* of it, the efficient Cause of all those inestimable Benefits, should be taught to all who are willing to learn the Principles of this the most useful of all the Sciences, to all who desire to know the secret Causes why some plants enrich, and others impoverish the Ground in which they grow; why different Methods of Husbandry produce different Effects, and in general to all who incline to study the Reasons for and against, the different Methods practised? They that do not study Agriculture as a Science do right only by chance, and that rarely happens Why then should Reason be so little exercised, as generally it is, in this Matter of the greatest Importance?' He then refers to the opinions of Virgil, and to the views expressed by Columella on the subject of teaching agriculture, and he urges the Society to take steps to found a professorship, or to secure an inspector of experiments, 'surely a practical farmer should be chosen, who could teach Rules established upon rational Experiments tried in our own country; one who has given Testimonies that he has studied, and does understand the Principles of Agriculture Your careful Endeavours to get a Fund settled for such a Professor or Inspector would crown your former labours. It will then be said and be certainly true, that you did all you could as *Improvers in the Knowledge of Agriculture*'

Maxwell proposed that the Society should address a Memorial to the King on the subject of a Professorship 'You are,' he wrote, 'a great Body of loyal subjects and generally of great Distinction, and I humbly think upon a proper

Application to his Majesty, you could not fail to have sufficient Influence to get such a Professor or Inspector named or both '

But alas! Neither professor nor inspector did Maxwell see, for within two years Prince Charles Edward had landed in Scotland, the Marquis of Tullibardine was rallying the Highlanders to the Stuart flag, and the loyalty of the Honourable Society was subjected to a strain which it could not withstand Most of the members took the advice of Duncan Forbes and held out for the King, but others, like the Duke of Perth and Lords Cromartie, Balmerino, and Lovat, followed Prince Charlie When peace was restored, the Honourable Society, and not a few of its members, had ceased to exist, but the purpose for which it was founded had been achieved, and the Spirit of the Improver lived on

One of the objects of the Honourable Society of Improvers was to develop local societies Two of these may be traced in Scotland before 1745, one in Buchan, the other in East Lothian The former appears to have been started about 1730 by James Ferguson of Pitfour among his Buchan tenantry Ferguson was a friend of Thomas Hope's and believed in his methods of 'preaching improvements' He supplied the members of the Buchan Society with books and he himself attended their meetings In 1735 this Society published a small volume which had been drawn up by the members at their meetings entitled 'A True Method of Treating Light Hazely Ground, or, an Exact Relation of the Practice of Farmers in Buchan containing Rules for Infields, Outfields, Haughs, and Laighs' In many respects this is a remarkable little work It relates exclusively to local farming, and while the inspiration may have come from Edinburgh, the book itself bears no evidence of outside influence Their independence is indeed a noteworthy characteristic of the members of this Buchan Society From certain references which appear in their 'Proceedings' it may be surmised that they were well acquainted with agricultural writers But instead of recounting the opinions of others, and speculating as to their value for Buchan, this Society of tenant farmers adopted the true scientific method, they described their practices in detail, discussed them fully, and, being satisfied that they were applicable to local conditions, they reduced their methods to rules But the Society were most careful to point out that these rules held only for the conditions of Buchan Their soil 'differs from all others in natural qualities,' it is therefore necessary to give 'uncommon rules in managing it' They even exclude land lying near the sea in their own immediate neighbourhood, 'in this relation,' they say, 'we make no record of our coast side neither are our Rules calculated for that part of the country, but are only to be received at two or three miles distance from the sea'

The Buchan Society's attitude to the agricultural practices recommended by others is well illustrated by the following comment on steeps for seed Several methods of steeping are mentioned by them, but they add 'This we doubt not may have some good effect, but frankly own we can give no advice from experience, and so refer the inquisitive to the elaborate works of elder practitioners' In matters too deep for them, their philosophy rested on a firm basis Here, for example, is an explanation of the early fruiting of wild oats This pestilent weed they urge all farmers to destroy by 'cropping the wild oats how soon they come out of the hose, who appear always about eight days before the tame. Thus is Providence so kind as to tack that to their nature which is the means of their own destruction'

Although improved practices did not reach Scotland for a century after they had been adopted in England, they spread much more rapidly among the northern people In 1720 there were but a few landowners who made any attempt at improvements in husbandry In 1723 the Honourable the Society of Improvers was formed, and ten years later we can trace a small society of Aberdeenshire tenants applying the scientific method to the common practice of Scottish farming. The tenant farmers of the North had educated men within their own ranks, and through these men a knowledge of improved practice quickly reached the others The compiler of the Buchan 'Rules,' James Arbuthnot, tenant of Wester Rora in the parish of Longside, was a type of this class He had received a classical education and belonged to a branch of a well-known family The verses of a local poet written on his death show him to have been a man greatly respected in Buchan A reference to men of the same class—the educated Scottish farmer of the eighteenth century—is made in a lecture given by the Rev Harry Stuart

to the Forfarshire Agricultural Association in 1853. Speaking of his own farming ancestors, Mr Stuart describes how his grandfather had been made heir to six relatives all in one month by the ambitions of Prince Charlie, and had to begin farming on his own account at seventeen; but before he settled to the plough he had wrestled hard with his books, had committed his Latin grammar to memory, and, as was then the custom in the better schools, had been wont to address the dominie in the Latin tongue. 'There were many such farmers then as he,' says Mr Stuart, 'reading their Livy to their breakfast and having a tilt at the fencing-foils in the evening with the young fellows. . . . After the fashion of the times he kept open house and I heard all the good and the bad of the new schools just opened discussed a thousand times over by his visitors, many of them retired farming officers, who had seen much in other countries and in a rough enough way, and who did a great deal in spiriting on improvements.' These men, representatives as a rule of a minor branch of some powerful family, fought when the country was at war and farmed when there was peace; they exercised a considerable influence on the development of agriculture, especially in the Highlands.

The second of the local Scottish societies, existing before 1745, was that established by an enlightened landowner, John Cockburn of Ormistown, in East Lothian. Robertson, in his 'Rural Recollections,' gives July 18, 1736, as the date of its formation. With Cockburn were associated Sir John Dalrymple and other country gentlemen. From a reference made to their meetings by Henry Home, it would appear that in this Society we have the origin of the 'farmers' dinner.' Home counsels landlords to 'convene' tenants once a year to a 'hearty meal' at which they were to be instructed in new methods of husbandry. 'It was by such means,' he adds, 'that the late John Cockburn of Ormistown promoted emulation and industry among his people.' But Cockburn did not confine himself to an annual dinner. Monthly meetings were held for the discussion of agricultural improvements, and these were much appreciated not only by Cockburn's tenants but by neighbouring landowners like the Earl of Stair and the Duke of Perth, who attended regularly. Even the '45 did not suppress these monthly meetings, and after Preston Pans the Duke of Perth was mindful enough of Ormistown to send troops to protect the members, so that they might quietly continue their criticisms of Tull and their appreciations of turnips. For which action, had Prince Charlie retained his hold on Scotland, the Duke might have been created first Chairman of the Scottish Board of Agriculture, a Department of State of which, even then, men were beginning to dream!

Maxwell tells us that the Dublin Society (established 1731) was formed in imitation of the Society of Improvers. It is clear when Arthur Young wrote that to the Dublin Society 'belongs the undisputed merit of being the father of all similar societies now existing in Europe' he meant that it was the oldest of existing agricultural societies, and not the first society of its kind. The Dublin Society soon after its formation received a Government grant and could therefore spend much more on its work than its Scottish prototype. Time will not permit of a reference to the work of this Society, but mention may be made of the experimental farm established by the unfortunate John Wynn Baker, under its auspices. The farm was started in 1764 and continued until about 1770. Schemes were drawn up by Baker in consultation with the Society, and an annual grant of 200*l* was made in support of the experiments; two volumes giving the results were issued. Baker was, as Arthur Young says, 'a very ingenious man' who worked hard for the Society, made experiments in agriculture, recorded meteorological information, manufactured implements, and wrote essays; but he lived in poverty and 'broke his heart' because of the Society's treatment of him. Young and he projected a literary partnership, but Baker's views on authorship could not be reconciled to the demands of the publishers of the time, and it was not until after Baker's death that Young realised in his 'Annals' (1784) the periodical publication which, with Baker, he had tried to start some ten years earlier.

In 1754 the Royal Society of Arts was established, and almost immediately afterwards it began to give attention to agriculture. A record of its valuable work written by Sir Henry Truman Wood has recently been published in the Society's 'Journal.'

The same year that saw the formation of the Royal Society of Arts brought

together in Edinburgh a small group of distinguished men who formed themselves into the Select Society The purposes were the discussion of philosophical questions and practice in public speaking The idea came from Allan Ramsay, an artist and son of the poet Alexander Wedderburn was elected Chairman (as Lord Loughborough, the first Scottish Lord Chancellor of England, he affixed the Seal that gave Sir John Sinclair his Board of Agriculture), and among the members were Adam Smith, David Hume, Henry Home (later Lord Kames), and William Robertson (afterwards Principal of Edinburgh University) This Society soon attracted all Edinburgh residents who were in any way distinguished But in one respect it was a failure, certain members, we are informed, always talked, and the wisdom of others was in danger of being suppressed and unavailing It is said, for example, that Adam Smith and David Hume never opened their lips! It appears therefore to have been decided that the Society's genius should be turned to practical objects, and within the Select Society a new organisation, the Edinburgh Society, was formed in 1755, 'for the encouragement of Arts, Sciences, Manufactures and Agriculture '—i e , for the same purposes as the Society of Arts had been established in London a few months earlier

An account of the Edinburgh Society is given by Ramsay in his 'History of the Highland and Agricultural Society of Scotland,' from which it appears that the methods of this society—the offering of premiums for live-stock and implements —were those which have since been everywhere adopted In 1759, for example we read that at the show of horses nine stallions were exhibited, 'all very good ' But the goodness of the stallions and of the objects did not bring prosperity to the Edinburgh Society, talent was more abundant than money in Edinburgh in the middle of the eighteenth century, subscriptions remained unpaid, the premium list had to be reduced, and finally the Select and the Edinburgh Societies disappeared together in 1765

The success of the Royal Society of England and the influence of the Honourable the Society of Improvers of Scotland did not escape notice on the Continent, and after the Peace of Aix-la-Chapelle (1748), when France realised the necessity of developing her agriculture, societies were established in that country The Marquis of Tourbilli, a well-known writer on agriculture, took the lead in forming a society at Tours, a second important society was formed in Brittany, and so useful did they prove that by 1761, Harte informs us, there were thirteen at work for the improvement of agriculture in France Each society was assigned a district, and in the larger districts subsidiary societies were formed, of these there were nineteen in 1761

The movement spread to other countries about the same time In 1751 George II founded an agricultural society in Hanover, which awarded half-yearly premiums for dissertations on agricultural subjects In 1759 the Swiss established a society in Berne, which later became the most important agricultural association in Europe An active society also began work in Tuscany before 1760

The value of the work of the early associations was also generally recognised in this country, and in the second half of the eighteenth century many others were formed Among them may be mentioned the Gordon's Mill (Aberdeen) Farming Club, the Highland and Agricultural Society, the British Wool Society, the Norwich, York and Bath Societies, and the local agricultural societies of Doncaster, Cornwall, Brecon, and Leicester

Before concluding these notes on the early associations let me ask your attention very briefly to some of the evidences of their influence on the agriculture of a later period

The chief aims of the early societies were to impress upon landowners in the first place the interest afforded by the study of agriculture and in the second the duty of providing an increased supply of food for the nation Nothing is more marked in the writings of such Improvers as Blith, Worlidge, Lisle, Laurence, and Mackintosh than their insistence on the importance of agriculture as a subject of study Until the educated among their fellow-countrymen could be interested in the principles of agriculture, it was clear to these far-seeing men that progress could not be made Exhortation, persuasion, and satire are employed by turns with the object of securing attention for agricultural questions.

Worlidge, for example, extols a country life and laments the fact that in his day the populace esteemed the country but a place for beasts, while the cities were for men; and Mackintosh of Borlum in upbraiding Scottish gentlemen for despising agriculture, is careful to indicate that the 'pertest Speaker and Despiser of the Farmer' he had met with was 'an upstart estated Spark, Son of a Merchant, who Cato, Cicero, and Varro, all say, don't put together Money so innocently, if the fairest dealing Merchant as the Countryman does'

The change in the attitude of the educated classes to agriculture that took place within a century of the formation of the Royal Society is indicated in all the works published after 1750 Hirtzel, of Berne, *e g*, in 'The Rural Socrates' (second edition, 1764) remarks 'It is no longer a controvertible point whether the science of Agriculture merits the distinguished attention of philosophical minds, and is the proper study of the most enlightened understanding, since the proof is beyond contradiction, that a judicious rural economy is one of the chief supports of the prosperity of a State' In Henry Home's dedication of 'The Gentleman Farmer' to the President of the Royal Society (1776), we find this passage. 'Agriculture justly claims to be the chief of arts, it enjoys beside the signal pre-eminence of combining deep philosophy with useful practice', and in the preface to the same work he says 'Our gentlemen who live in the country have become active and industrious They embellish their fields, improve their lands, and give bread to thousands' He contrasts these pursuits with those which formerly occupied the country gentleman 'His train of ideas was confined to dogs, horses, hares, foxes, not a rational idea entered the train, not a spark of patriotism, nothing done for the public'

How unlike the state of affairs described by Home were the conditions in a country resembling Britain, but in which the Spirit of the Improver had not been awakened, may be indicated by a quotation from a report on the farming of Holstein and Mecklenburg sent to Sir John Sinclair in 1794 The writer, M Voght, states that the agriculture of North Germany was fifty years behind that of England, and explains its depressed state by saying 'Our noblemen are no farmers, and our farmers no gentlemen, our authors on agriculture possess no cultivated land, and those few who could give to the public the precious results of long experience and labour would starve their printer for want of readers'

The landowner of North Germany, towards the end of the eighteenth century, was, indeed, in very much the same state as the landowner of Britain in the first quarter, and it is when we compare the conditions described by Lisle, Mackintosh, Home, and Voght, that we begin to appreciate how much British farming owes to such associations as the Royal Society of England and the Honourable the Society of Improvers of Scotland Had not the interest of landowners, and of the educated classes generally, been secured, there is no reason to suppose that the agriculture of Britain in 1794 would have been markedly in advance of that of Germany

I have already pointed out that both in England and Scotland the first impetus towards progress was economic in its character, and throughout the seventeenth and eighteenth centuries economic causes were constantly accelerating the improvement of agriculture, but we must not make the mistake of supposing that a rise in prices necessarily brings about improvements in husbandry A motive for improvement is provided and more labour may be drawn to agriculture, but it does not follow that there will be a real advance, and that there will be more food produced for the use of workers in other industries Without changes of system, *i e*, without improvements based on new discoveries, the effect of a rise of prices in a self-supporting country would merely be to alter the proportion of the population engaged in agriculture, and to form congested districts This was the danger that threatened England early in the seventeenth and Scotland early in the eighteenth centuries, but fortunately for each country an intellectual revival followed close on the rise in prices, and attention was directed not only to the necessity for more food, but to the need for improvements which would afford a surplus for the support of the industrial classes

As Adam Dickson, writing at the time, and Thorold Rogers, reviewing economic history a century later, both point out, there is no question that the rise of the mercantile class led to a development of the commercial spirit among the landowners of the eighteenth century, but this is not the particular aspect

of the economic question that is suggested by a study of the records of these societies and of the works of the early Improvers Their first contention was that agriculture was a subject worthy of study for its own sake, their second that it was worthy of study for the sake of the nation The appeal to self-interest occurs, it is true, but it is not insisted on as being the all-important consideration

At the present time, when so much of our food comes from other countries, we do not, perhaps, sufficiently realise the extent to which the commercial prosperity of Britain was built up by the aid of, or depended upon an improved agriculture, but the relationship of industrial progress to agriculture was never lost sight of by the early Improvers, and not only the food-supply of the industrial classes, but the system of agriculture best suited for rearing the type of worker required for developing new industries was carefully considered by them

Within recent years the Improvers of the eighteenth and early nineteenth centuries have been much criticised for their land policy, their enclosures, and their treatment of labourers, but one thing at least the agriculturists of 1760-1815 saw more clearly than their modern critics, they recognised that if their country was to become a great manufacturing nation, more food must be grown, and to this task they applied themselves so successfully that, as Porter points out, the land of Great Britain, which, in 1760, supported about eight million inhabitants, in 1831 supported sixteen millions When we reflect that the implements of husbandry were rude, that thorough drainage had not been introduced, that artificial manures (except crushed bones) were hardly known, that oilcakes were scarce, that grain was too valuable to be given freely to cattle, that in bad seasons live-stock had to be starved so that men might be fed, that in good seasons prices fell rapidly, and with them farming profits, and that credit was difficult to obtain and interest high, those of us who know some thing about the ordinary work of the farmer can realise the strenuous efforts that must have been necessary to wring from land a sufficiency to feed this rapidly growing nation and to maintain it in health and comparative comfort Even as late as 1836 Porter shows that it would have been impossible to feed any considerable part of the people on imported food 'To supply the United Kingdom with the single article of wheat,' he says, 'would call for the employment of more than twice the amount of shipping which now annually enters our ports'

Nor was it for man only that an increased food-supply was required, between 1760 and 1831 there was a great addition to the horse population, owing to the improvement of roads and the substitution of horses for oxen on farms To the increase in the number of horses contemporary writers attributed in some degree the high prices ruling at the end of the eighteenth century

Part of the additional food-supply was obtained by enclosing about seven million acres of land between 1760 and 1834, but as more than three times this area must already have been enclosed, as much of the land enclosed after 1760 was of poor quality, and as all of it had formerly contributed in some degree to the food-supply of the country, it is obvious that between 1760 and 1834 the rate of production per acre must have been largely increased

Improvements in the art of agriculture cannot be rapidly introduced, there is first of all an experimental stage, and when improved methods have been learned they pass but slowly from district to district Before any marked advance in the art can take place, there must therefore occur a period during which a foundation is being laid It was about 1760 that our population began to increase rapidly, and it was then that agriculturists were called upon to produce more food As we have seen, they were able to double the food-supply in seventy years It cannot be doubted that this marvellous feat was rendered possible by the pioneer societies of the preceding century, or that it was the spirit of the Improver, which the early associations had fostered, that animated the men from whom Arthur Young and Sir John Sinclair learned If, in place of those enterprising agriculturists whose improvements are described in the Reports of the first Board of Agriculture, our shires had been occupied by the dull-witted country gentlemen referred to by Lisle, or the 'upstart sparks' condemned by Mackintosh, the history of this country must have been very different. Behind the military and naval victories which made Britain a great Power, was a commissariat supported by the agricultural classes For the great

industrial army which the genius of Arkwright, Watt, and other inventors provided with employment there was raised an ever-increasing food-supply Political and industrial development alike depended on the rate of increase of the population, and this again on the rate at which the means of subsistence could be raised from British soil.

Although the economic position has undergone a revolution there is still work for the Improver; no longer indeed do our industrial classes depend for subsistence on the surplus products of the British farmer, but after a long period of forgetfulness, once again it has been recognised that a progressive agriculture is essential to the well-being of the nation This is not the time to discuss the nature of the questions which press upon us to-day, but let us not forget that they are our questions To this newly formed Section of the British Association has descended the task of the early associations, it is the privilege of its members to preserve, and to hand down to their successors, that Spirit of the Improver which animated alike the ancient writers of Greece and Rome and the British societies of the seventeenth and eighteenth centuries, and to-day we may take to ourselves the exhortation of Walter Blith, for his words apply to Section M as they did to its predecessors, 'from you, too, I expect and waite for more discoveries of some thing, I scarce know what to name it, which lies yet in obscurity, but I will call it the Improvement of the Improver.'

The following Papers were then read —

1 *Some Important Chemical and Bacteriological Problems in relation to Agriculture* *By* Professor F LOHNIS

---

2 *The Interpretation of Milk Records* *By* W GAVIN, *B A*

The practice of keeping milk records seems at last to be gaining ground throughout the country, and in a few years' time a very considerable amount of material will have accumulated for the study of the dairy cow The author, working on the records kept for the last twenty-four years on Lord Rayleigh's dairy-farms, has endeavoured to deal with the preliminary difficulties that will arise in the interpretation of these records

In any statistical study of the inheritance of milk-yield, or indeed in any systematised breeding where more than a few cows are dealt with, it becomes necessary to define a cow's milking capability by a single and unqualified figure By milking capability is meant, of course, the cow's individual somatic power of giving milk No reference is intended to her genetic qualifications in this respect

Breeders generally rely on such figures as total yield per calf, total yield per calendar year, average per week, &c , but the enormous fluctuations found in the same animal show that all these are subject to a variety of outside influences It is therefore necessary —

(*a*) To select a figure affected by the minimum number of these influences, and

(*b*) To estimate as accurately as is possible the effect of those influences under which it does fall

After preliminary examination of the material, it was decided to see which of the following figures would give the most satisfactory basis of comparison, namely :—

Maximum yield per day

Average yield per day, fifth to twelfth week after calving

Maximum yield per day maintained or exceeded for not less than three weeks (*i e* , three weekly entries)

(a) *Selection of the Figure*

(i) When normal lactations only were considered, all the above figures showed coefficients of variability $\left(\frac{\text{(standard deviation)}}{\text{mean}}\right)$ almost identical with that of lactation totals

(ii) When *all* cows were included, however, the variability of totals was increased 25 per cent, while that of the other three figures remained almost unchanged

(iii) In order to show that these figures really were closely connected with the inherent capabilities of a cow, and so with the yield the owner might expect to get under ordinary circumstances, correlation coefficients were determined between them and lactation totals, both for *normal* lactations and for various groups of *similar abnormal* lactations These were found to vary between —

$$+ \cdot 800 \pm \cdot 007$$
$$+ \cdot 904 \pm \cdot 005$$

(iv) All were sufficiently high to justify the use of any of the figures, but a comparison of the coefficients gave an almost constant indication of their respective merits

(b) *Effect of Exterior Influences*

By the choice of any of above figures .—

(i) Two important causes of variability have been eliminated, namely —

Number of weeks in milk
Interval between calving and subsequent service

(ii) The influence of food, weather, and general treatment has been minimised

(iii) But —

Age of cow,
Length of rest before calving,
Season of year of calving,

must be statistically dealt with

If a standard figure could be agreed upon for the expression of a cow's milking capabilities, it seems that the problems of the inheritance of milk yield, and of its possible correlation with other characteristics, would be materially advanced They could, at any rate, be dealt with on the same basis, and so with strictly comparable results, in all parts of the country

---

3 *On the Effect of Heavy Root-Feeding on the Yield and Composition of Milk By* ALEXANDER LAUDER, *D Sc*, *and* T W FAGAN, *M A*

The object of the experiments was to test the effect of a ration consisting largely of roots on the yield and composition of milk, and incidentally to determine how far turnips could profitably replace the more concentrated and expensive foods commonly employed in feeding dairy cattle

Three separate experiments have been made—the first in 1909, when twenty cows were under experiment, the second in 1910-11, with twenty-two cows, and the third in 1911-12, with eighteen cows For each experiment two lots of cows, as nearly equal as possible in respect of age, period of lactation, and yield and quality of milk, were selected from the herd Before the experiment began there was a preliminary period of trial of about three weeks in length, in order to complete the adjustment of the two lots. During this preliminary period all the foods to be experimented with were fed. The cows were then gradually put on to the experimental rations In experiment III, after the experimental rations had been given for eight to ten weeks respectively, the rations were crossed The change was effected gradually, so as to introduce as little disturbance as possible, and then the experiment was continued for another four to six weeks

EXPERIMENT III. (1911–12).

Lot I. (Turnip Ration).	Pounds	Lot II. (Ordinary Concentrated Ration).	Pounds
Bean meal	2	Bean meal	2
Bran	2	Bran	2
Turnips	112	Pease meal	4
Hay	15	Dried brewers' grains	2
		Turnips	40
		Hay	15
Albuminoid ratio, 1 14.		Albuminoid ratio, 1 7 6.	
Total dry matter in ration, 28 6 pounds		Total dry matter in ration, 26·7 pounds.	

In addition, straw was fed to both lots

The turnip ration contained only 4 pounds of concentrated food as against 10 pounds in the ordinary ration, on the other hand, it contained 72 pounds more turnips, and on the average contained about 1¾ pound more dry matter than the ordinary ration

The cows on the turnip ration received daily nearly four and a half gallons more water per head than those on the other ration The results showed —

1 It is not from the ration containing the greatest weight of digestible fat that the richest milk has been obtained

2 The much larger amount of fat obtained in the milk than was given in the ration If allowance is made for the indigestible fat in the ration the difference is even more striking In 1911-12, for example, the turnip ration contained only 171 pounds of digestible fat, and the ordinary ration only 247 pounds; the yield of fat in the milk over the amount fed was 358 pounds in the case of Lot I, and 263 pounds in the case of Lot II The larger secretion of fat, which has always been obtained from the cows fed on the turnip ration, appears to indicate that the easily digestible carbohydrates contained in the turnips are specially suitable for fat formation

Summary and Conclusions

Taking the results of the three experiments together we may draw the following conclusions —

1 The feeding of a ration containing a large quantity of water does not increase the percentage of water in the milk or reduce the percentage of fat

2 In all three experiments the greater yield of milk was obtained from the cows on the concentrated ration On the other hand, the milk from the cows on the turnip ration contained a higher percentage of fat, and a greater total weight of fat was contained in the milk

---

4. *The Fat-globules of Milk in relation to Churning* *By* W. F. COOPER, *B A*, W H NUTTALL, *F I.C*, *and* G A. FREAK, *B Sc.*

Creams vary in their behaviour during churning, not only creams of different breeds of cows, but frequently cows of the same breed show variations Amongst other factors, some property of the fat-globules may give rise to this effect

The term 'Churnability' is used for this varying behaviour during churning

Work was carried on at the Royal Agricultural Shows from 1909 to 1910. A full account is published in the 'Journal of Agricultural Science,' vol 4, p. 150

The only method used, previously, for determining the globules was that of Babcock, the milk being placed in capillary tubes The authors adopted a modification of the Thoma-Zeiss hæmocytometer, photographing the milk in the cell This method makes it possible to check results

The globules in milks of various breeds were determined; the mean size of globule in different breeds, and in individual cows of the same breed, was ascertained, and curves were plotted, but the conclusion was that there was almost as much variation in different milks of the same breed of cows as in average milks of different breeds, and that, for the purpose of ascertaining the

variation in churnability, due to the fat-globules, each cream must be considered as being obtained, not from milk of any particular breed, but from milk of a particular mean-sized globule

Before this could be determined it was necessary to ascertain the optimum temperature for churning, and to determine the amount of loss in churning at various temperatures

In the work now published the optimum temperature was ascertained and found to be 52° F for all creams, that is to say, the lower the temperature the less fat is left in the butter-milk

With sweet cream, as much as 30 per cent of the total fat may be lost in the butter-milk if too high a temperature is used With ripened cream, as much as 20 per cent may be lost Curves are drawn showing the loss due to too high a temperature

A series of analyses of the nitrogen-containing constituents was given, with photomicrographs and measurements of the globules of the milks No correlation between any of these constituents and fat-globules could be ascertained

The question of a membrane surrounding the fat-globule was considered, and an attempt to repeat Storch's work discussed An artificial milk was prepared, all the constituents being 'membraneless' A film of this milk, dried and stained, showed the same characters under the microscope as an ordinary pure milk So it is considered that Storch's membrane does not exist, but that the colloids in milk are absorbed by the fat-globules so as to give rise to a resemblance of a membrane Storch's analytical figures were explained on this assumption

Figures were given proving that the presence of large fat-globules in a milk enables more of the smaller ones to be separated in a mechanical separator

Results of experiments were given, in which foods of varying 'ratios' were given to cows, to determine their effect upon the size of fat-globules

5 *The Oat Kernel* *By* Professor R A Berry, *F I C*

A summary of the more important results obtained from an extensive series of analyses of the oat kernel extending over several years, and now numbering over seven hundred complete analyses, was given The oats were grown at the experiment station of the West of Scotland Agricultural College, on various farms in the West of Scotland, and, in addition, in 1911 at a few centres in the South of England and Wales

The results are best considered under the following headings —

Variety —By tabulating the grain of over a hundred varieties, according to the percentage and weight of kernel, along with the chemical analyses it is possible to distinguish several more or less well-defined types *The White Grains* group into (1) Small grains with a thin husk, a high percentage of oil, and an average percentage of nitrogen These are characteristic of and include the old Scotch varieties with the newer selected strains from same (2) Large grains fall into two groups (*a*) A thick husk, a low percentage of oil, and high nitrogen, (*b*) a thin husk, a higher percentage of oil, and a lower nitrogen (3) Grains intermediate in character and chemical composition to the large and small include the bulk of the newer hybrid varieties *The Black Grains* grade into (1) small grains with a thick husk, low oil, and average nitrogen (2) Medium grains with a thick husk, high oil, and low nitrogen (3) Large grains with a thin husk and the richest kernel of the cultivated oats These are the winter oats The reddish and yellow grains form separate groups The wild oat surpasses all in richness of kernel

Variation of the Kernel —In this respect the results show that climate is the most disturbing factor Distinguishing characters associated with a certain set of climatic conditions become greatly modified and, in some cases, almost obliterated when the conditions are radically changed Scotch seed sown in the South of England and Wales in the warm and dry summer of 1911 yielded grain of a smaller and drier kernel, a thicker husk, higher nitrogen, and lower oil and weight per bushel than grain grown in Scotland The cooler and more humid climate of the West of Scotland and the longer maturation period produce in

the grain the opposite tendencies to those mentioned above, except on the poorer soils and drier localities The average variation in the grain of over sixty-three varieties grown annually from 1909 to 1911, under the less extreme climatic conditions prevailing at the experiment station, was in comparison small The unusually warm summer of 1911, however, gave a slightly larger kernel with a thinner husk, slightly poorer in oil and richer in nitrogen than the grain of 1909-10, and would resemble the effect of the normal English summer Time of sowing and ordinary dressings of manures produce little effect on the grain Soils rich in nitrogen produce grain richer in this element

Foreign and Colonial oats are usually, but not invariably, small, thick husked, relatively rich in oil and nitrogen, and low weight per bushel, as a rule they have a short maturation period

Oil and Nitrogen—Micro-chemical tests show the oil to be located in the aleurone layer and the embryo The latter forms from 2 5 to 4 per cent of the kernel, and contains between 11 25 per cent and 12 25 per cent of the oil, and between 4 5 per cent and 6 5 per cent of the protein of the whole kernel The smaller grains of the same variety are invariably richer in oil but slightly poorer in nitrogen Analyses made every three days during the formation and maturation of the grain show the oil to increase rapidly in the first half, then remain stationary, whilst the nitrogen increases all through the period The results seem to show that the variation of the principal constituents of the oat kernel is greater than is usually supposed

Flavour in oatmeal in relation to chemical composition, milling capacity, and yield per acre was dealt with

---

FRIDAY, SEPTEMBER 6

The following Papers were read —

1 *The Sources of the Nation's Food Supply* *By* R H Rew, *C B*

2 *Scottish Agricultural Changes* *By* Major P G Craigie, *C.B*

As a sphere of agricultural production Scotland offers a territory of 19,000,000 acres, of which fully 14 per cent lies over the 1,500 feet limit, and nearly one-half is made up of rough hill-grazings rising in part over that level This leaves for permanent cultivated pasture for rotation grasses and clovers, and for the surface over which the plough can annually range, not quite 5,000,000 acres The 'cultivated area' can be shown to have lost and gained in the interval if the statistics of the Highland and Agricultural Society in 1854-56 be taken as the starting point

Adding their estimate of 238,000 acres of arable land on the minor farms, 42,000 in number, to their more detailed analysis of the surface farmed by 43,000 larger occupiers, we find 3,750,000 acres was then regarded as 'arable' The advent of the Agricultural Returns of 1886 suggest as the feature of the intervening decade a large and rapid shrinkage of the arable acreage Taking a five-year average up to 1870, only 3,360,000 acres could be so regarded This figure rose to 3,367,000 acres in 1886-90 and did not fall below 3,500,000 acres till the twentieth century opened It was 3,460,000 acres in 1901-05 and just under 3,400,000 in 1906-10, and therefore at the date of the new Census of Production. The changes between 1854-56 and 1866-70 included a diminution of 386,000 acres coincident with the abandonment of over 150,000 acres of wheat after the abnormally high prices of the Crimean War disappeared The later changes, which we can measure more exactly from 1870 to 1910, show that some 200,000 acres of grain were lost, including 74,000 further acres of wheat, there were nearly 100,000 acres of turnips and potatoes less, balanced by a growth of nearly 200,000 acres of rotation grasses. The permanent but cultivated grass in the same forty years augmented steadily from a round million to 1,500,000 acres. If crop areas are less the yields are all higher, and the wheat crop of the Census

year (1908) reached 41 bushels per acre against less than 28 in the fifties, barley 36 against 33, and oats 39 against 32, while the potato yield of under four tons reached seven tons in 1908

Concurrently the cattle maintained in 1854-56 exceeded 1,000,000 head They rose to 1,157,000 in 1884-86, exceeded 1,200,000 head for 1890 to 1906, stood at 1,174,000 in 1908, and are again at 1,200,000 now The sheep of 1854-56 only numbered 5,900,000. By 1884-86 they reached 6,848,000, reached a maximum of 7,623,000 in 1891, and with only two drops below the seven-millions level were 7,439,000 in 1898, and are still 7,164,000 Herein the Scottish flocks maintained a record over all those of Western Europe, where the loss of sheep was large and significant The pig stock of Scotland has always been a very small factor, but the level of 1908 at 144,000 was well above the total of the fifties, and is to-day over 170,000

In the light of the new Census the saleable output of Scottish agriculture, however, only reaches 23,150,000*l* per annum, the crops so far as sold accounting for over a fourth, or 6,400,000*l*, the animals and animal products 16,250,000*l*, with 500,000*l* from 'fruit, flowers, and timber,' of which the fruit is about two-thirds What these figures teach is a problem worthy of this new Section's attentive study If the timber sales, calculated at 181,000*l* on 875,000 acres, and reaching thus only 4*s* 2*d* per acre, be deducted, the remaining agricultural area of under 14,000,000 acres would appear to return less than 33*s* per acre, while the Census report suggests that the rough grazings, of which Scotland shows 9,080,000 acres in its utilised area, can be reckoned to yield only 10*s* to 12*s* an acre of saleable output, if indeed this figure is not too high

These features have to be reckoned with in any survey of the remaining scope for agricultural development, and give point to the directions in which the prospects are most hopeful The prominent share which the livestock of the farm contributes to the total is enforced, and the student will find in the details now available as to the relative production of differing areas, the prevailing distribution of the land in farm units of various magnitude, and the economic or non-economic expenditure of labour force, topics which bear very closely indeed on the scope for scientific discovery

3 *A Consideration of the Profits realised from the usual Field Crops, more especially from Temporary Pasture* *By* Professor JAMES WILSON, *M A*, *B Sc*

Balance-sheets are seldom made up for individual crops, seldomest for the grass crop Yet this is the only way in which we can find whether a crop pays or does not pay The following table is drawn up to show, for a few crops, the cost of production, the value, and the profits realised per acre on land of average quality The land is reckoned so far away from a large centre of population that 'proximity' rent may be neglected It is assumed to be worked upon the ordinary six-course rotation—viz, lea oats, turnips or potatoes, oats, hay, grass, grass The farmyard manure is all applied to the roots and potatoes, the potatoes getting about a half more than the turnips The turnips get, in addition, 1 cwt of ammonium sulphate and 4 cwt of superphosphate, while the potatoes get these two manures *plus* 1 cwt of muriate of potash Larger dressings to roots and potatoes and dressings of artificial manures to some other crops would increase both yields and profits, but our present purpose is not to depart from the average custom, so as to compare the profits realised from a few average crops under average conditions

The turnip crop is charged with half the farmyard manure, with half the superphosphate, and with all the ammonium sulphate The potato crop is similarly charged, at a slightly higher rate Of the residue, two-thirds is charged against the succeeding grain crop, and one-third against the hay The grass crop is credited with accumulating fertility at the rate of 5*s* per annum, and this is charged against the lea oat crop Each crop is charged with 1*l* an acre for rent, and with all the labour and other outlays incidental to its production, saving, storing, and delivery An additional 1*l* is charged against each crop for expenses common to all. This represents rates, taxes, and insurance,

interest on working capital, upkeep of implements and working stock, occasional fencing, draining and pruning, idle time of horses and men, and general management and business expenses

Crop	Cost of Production	Value	Profit
	£ s d.	£ s. d.	£ s. d.
Lea oats, say, 5 qrs.	5 7 6	7 10 0	2 2 6
Turnips, say, 20 tons	8 0 0	10 0 0	2 0 0
Potatoes, say, 8 tons	13 10 0	17 0 0	3 10 0
Oats after roots, nearly 6 qrs.	6 0 0	8 2 6	2 2 6
Hay, say, 35 cwt.	4 2 6	6 2 6	2 0 0
Grass	2 2 6	2 2 6	—

The above figures suggest that the policy of growing temporary pastures, so common in the East of Scotland, may be a severe handicap in agricultural production It has some advantages Temporary pasture is excellent for the rearing and early maturing of high-class cattle and sheep, it is also, when well laid down, a means of accumulating fertility, and it fits in with our system of farming, but it is doubtful whether these advantages compensate for the difference between the returns from grass and those from roots, grain, and forage on similar land

The purpose of this paper was to raise this important economic question

4. *The Influence of Origin and Topography on Grasslands.* *By* W G. Smith, *B Sc , Ph D , and* C B Crampton, *M.B., C.M.*

The extent and distribution of grassland in each district of Britain depends much on the economic requirements, but the natural productive capacity is primarily determined by the nature of the soil and vegetation resulting from the past and present influences of climate and topography, and the distribution of the rocks

Extensive tracts of existing grasslands have, under man's operations, replaced other types of vegetation, such as woodland, heath, moor, and marsh Such grassland is liable to change, since it is only a phase introduced into the history of the vegetation

Other areas of grassland are of natural origin, and remain relatively constant under conditions which alter very slowly

Grassland may be grouped into (1) natural, (2) artificially induced The first group may be further sub-divided into (*a*) stable, (*b*) migratory according to its natural origin

The area of stable grassland in Britain is limited, *e g* , chalk downs, and exposed hills and bosses of limestones and basic igneous rocks The migratory types are widely distributed on alluvial areas and rain-washed slopes along the river and coastal belts, and on the flanks of mountains

The changes which lead naturally to the evolution of grassland and other changes leading to its retrogression are therefore to be specially considered where maintenance or improvement of grasslands is in view It is suggested that these conditions, taken in conjunction with observations on experimental plots, may aid in correlating information on different types of grassland

The stable types of grassland apparently owe their existence to the nature of the rocks and to the physiography which limits the growth of trees and prevents leaching of the surface or stagnancy Apart from the stable types there are the migratory types mentioned below .—

(*a*) Flushing of the slopes of moorland hills with water derived from springs, or with surface water bearing rain-wash, is favourable to the formation of grassland. This is specially well developed where the rocks are rich in lime or other bases, and where the flushing is temporary and periodic

(*b*) Recent deposits of alluvial sandy clay loams in the higher parts of stream-courses support other types of grassland.

(*c*) Other types are formed on the alluvial clay loams of the flood plains in the lower parts of river courses.

(*d*) Maritime types occur in succession to salt-marsh on coastal flats, and also on steep coastal contours exposed to wind, salt spray and earth-creep, and where the nature of the surface prevents rapid leaching and the formation of heath.

The following conditions lead to the retrogression of grassland —

(*a*) In moorland districts, invasion by acid, humous, and ferruginous waters leads to deterioration, and in the case of alluvial sandy loams to the formation of pan and consequent stagnation and reversion to moorland.

(*b*) Continued leaching by rain-water removes the soluble salts from the upper layers of porous sandy loams, and leads to production of heath.

(*c*) Alluvial grasslands and those of moorland flushes deteriorate by leaching when flooding is prevented The low-lying clay loam alluvial suffers mainly from insufficient drainage.

(*d*) Accumulation of humus because of acidity or insufficient grazing discourages the more valuable grasses

(*e*) Grasslands may suffer depletion slowly through the continuous removal of wool and carcase

---

5 *Scotland as a Fruit-growing Country. By* G P Berry.

Climate —Although the average maximum summer temperature of Scotland is several degrees below that of the extreme southerly districts of England, and our average minimum winter temperature is often considerably lower than the afore-mentioned districts, there are many counties and portions of counties where the finest of hardy fruits can be grown, and grown better than in the warmer districts of the south, where drought is often more extreme and pests and fungoid diseases more numerous and virulent In Scotland wind is a factor which often dominates the situation, and necessitates in fruit-growing careful selection as to natural shelter, as well as the planting of shelter belts and hedges which will grow rapidly The dwarfest forms of trees have also to be selected in the case of the apple, pear, and plum, to mitigate the necessity for high hedges One of the most suitable plants for this purpose in Scotland, as in other parts, is the Myrobelle (*Prunus Myrabolana*)

Late spring and early summer frosts are the worst enemy of the Scottish fruit-grower, and up to the present little has been done in the way of smudge fires, although where experimented with the results have not been unsatisfactory, and something might be done along this line.

Suitable Districts —The fruit-growing districts of Scotland are largely confined to two counties, Perth and Lanark, the former comprising the famous Carse of Gowrie, extending from Dundee to Perth, along the side of the Tay estuary, and principally on the Perthshire side. The north side from Dundee up to Perth has been used for fruit-growing from remote periods, Auchterarder and Blairgowrie districts being recent developments

Fruit-growing in the county of Lanark is largely confined to the Valley of the Clyde Tomato growing has also been developed in the district from Wishaw to Lanark

Forfarshire has of late years had considerable areas laid down to raspberries East Lothian, one of our finest agricultural counties, has a considerable area under fruit The fruit-growing district of Midlothian might be said to be confined to a radius of eight miles on the east, south, and western sides of the city of Edinburgh

The Carse of Stirling and Falkirk furnishes much suitable ground for fruit, but the presence of coal and iron has somewhat deterred the fruit-grower from developing in this district

Around Aberdeen considerable quantities of fruit are grown on a stiff clayey loam, strawberries being the principal small-fruit crop.

Soils —The soils on which fruit is grown show a great variation, from stiff clay in the Carse of Gowrie and Aberdeen to medium and light sandy soils, as in the Clyde Valley and Mid and East Lothian,

Manuring.—Many of the old orchards in Scotland are still under grass No feeding materials, natural or artificial, are applied, with the result that most are in an impoverished condition. On the other hand, where new plantations are being laid down by enterprising men, more attention is being paid to feeding, and, to help such, extensive experiments are being carried out by the East of Scotland College The importance of the application of manure in autumn in preference to the dead of winter and early spring is impressing itself on all thinking fruit-growers

Fruit Areas—The area under large fruit in Scotland is 2,011¼ acres, made up as follows .—

	Acres
Apples	789¾
Pears	186½
Cherries	23
Plums	291¾
Mixed	720¼
	2,011¼

The area under small fruit in Scotland amounts to 7,912½ acres, as follows —

	Acres
Strawberries	2,951
Raspberries	2,326½
Currants and Gooseberries	1,277¼
Mixed	1,357¾
	7,912½

Crops and Prices—*Strawberries,* on medium soil, 2 tons 4 cwt per acre, and on stiff, clayey soil, 3 tons per acre, representing a value of from 80*l* to 100*l* per acre *Raspberries* up to almost 6 tons per acre The average prices fluctuate very considerably, from 8*l* per ton in 1909 to 25*l* per ton in 1911 *Black Currants* command often 6*d* per pound wholesale *Apples,* culinary varieties, grown on Paradise stock planted 10 feet apart, firsts will command 2*s* 6*d.* per stone, seconds, 1*s* 6*d* , and thirds, 1*s* , and at ten years old may be expected to yield 40*l* to 45*l* per acre *Plums* command from 2*d* to 5*d* per pound according to crop and cultivation.

6 *Farming in Forfarshire* *By* R G White, *M Sc*

MONDAY, SEPTEMBER 9

Joint Discussion with Section A (Meteorological Department) on the Application of Meteorological Information to Agricultural Practice Opened by Dr W N Shaw, *F R S*

Syllabus of Questions on the relation between Meteorological Information and Agricultural Practice *By* Dr W. N Shaw, *F R S*

Climate in the Average Year

1 What crops are grown in what counties? and why? What limits the selection of crops in the different counties?

2 What aspects or positions are specially favourable for crops of different characters—fruit, vegetables, trees?

3. What is the relation between climate and crops in respect of (1) quantity, (2) quality, (3) time of harvest?

4 How much of (1) time, (2) sunlight, (3) warmth, (4) humidity of the air, (5) rainfall, is required for the best crop of any kind for the best forest growth?

5. What is accumulated temperature, and what is its use in agriculture? Why is the temperature of 42° F. selected as the base for calculating accumulated temperature? Is the same base suitable for all crops?

The Variation of Seasons

6 What effects do the differences of season as represented by rainfall, moisture, air temperature, earth temperature, snow, sunshine, have upon the crops in respect of (1) quantity, (2) time of harvest?

7 Is the effect different according to the nature of the soil?

8 What deviations of the seasons from the normal represent (1) a good year for any particular crop? (2) a bad year?

9 Can treatment of the soil protect against the effect of adverse seasons?

10 Can any economy be secured by adjusting the courses according to a knowledge of the weather of past seasons, and their known influence upon the various crops?

11 What action should be taken in the case of ground being (1) under snow, (2) under water, (3) dry, for an exceptionally long period?

12 What amount of rain can fall within a day, two days, three days, a week, a fortnight, a month, without causing floods? in winter? after a frost? in summer?

13 What is the local relation between rainfall and water supply in wells and rivers?

14 What is the longest drought that can be supported without suspension of farming operations of various kinds (growing crops or stock) on chalk or porous subsoils? on clay or non-porous subsoils?

15 How long can young growth do without water before hope of recovery has to be given up?

16 What is the relation between the prevalent diseases of plants and animals and the previous weather?

Inclement or Tempestuous Weather

17 What is the actual and percentage annual loss of crops on account of inclement weather?

18 What are the facts and figures upon which the rates of premium for insurance against damage by rain, hail, snow, frost, lightning, fogs, and drought are based?

19 What are the earliest dates in autumn and the latest dates in spring when killing frosts have been experienced? How do they depend upon situation?

20 What precautions other than insurance can be taken against the loss of crops or stock?

The following Papers were then read:—

1 '*Surface*' *Climate* *By* W Lawrence Balls, *M A*

Investigation of the 'Surface Climate' is of immediate interest to most biologists Such components as temperature, humidity, and wind are obviously altered amongst vegetation The extent of this alteration, within even a few inches of altitude, is not fully realised by all students of plant physiology, agriculture, and oecology A development of this investigation is the natural result of greater precision in plant physiology, entailing attempts at elucidation of physiological processes under the multiplex factors of field conditions.

A striking example has been recently demonstrated by the writer with regard to the cotton crop in Egypt, in that a puff of wind arising during an otherwise calm, clear night will raise the temperature of the crop by more than 5° C Since the growth of the plant is controlled chiefly by night-temperature, such a rise is not without importance

The explanation lies in the removal of air which has been chilled by radia-

tion from the plant, and its replacement by air at 'screen-temperature' Transpiration of water from the plant is negligible at night

The usual Egyptian paradox follows, since the wind which cools the grower warms the plant

2 *The Action of Quicklime on the Soil*
By H. B Hutchinson, *Ph D*

An account of experiments designed to show how far the micro-organisms of the soil are affected by applications of caustic lime was given The addition of small quantities of quicklime to field and garden soils stimulates general bacterial growth, but large quantities cause an initial depression in the numbers of bacteria and the destruction of certain large protozoa, and a cessation of all biological processes

Conversion of the lime from the caustic form into the carbonate or combination with soil compounds is followed by a great increase in the numbers of bacteria and increased ammonification of soil compounds

The length of the period during which bacterial growth is suspended would appear to be determined by the quantity of lime applied, the initial reaction of the soil, and the amount of organic matter present

Pot experiments have been carried out with variously limed soils, and the crop results show close agreement with those obtained by bacteriological and chemical analyses

3 *Studies on Nitrogen Assimilation by Free-living Organisms*
By H B Hutchinson, *Ph D*

Plots of land, when allowed to run wild for some years, show a considerable accumulation of nitrogen in the upper layers of the soil This has been attributed to the utilisation of the plant residues for nitrogen assimilation by such organisms as *Azotobacter chroococcum*

Attempts to induce similar changes in field soils have been made at Rothamsted, and the halves of two of the continuous barley plots on Hoos Field have received spring or autumn applications of sugar or starch for some years

Spring applications of carbohydrates were made in the four years 1906 to 1909, and were followed by decreased crop yields Laboratory experiments showed an increase of general saprophytic bacteria and a withdrawal of available nitrogenous plant-food from circulation in the soil It also appeared probable that the soil temperature obtaining in spring was too low to allow of a vigorous growth of the nitrogen-fixing organisms in the soil Autumn applications were made in 1909 and 1910 and resulted in a decided increase of yield over the control plot. The results are shown in the following table —

Hoos Field Barley Effects of Sugar (or Starch) on the Amount of Produce (Plot 40, Complete Minerals)

Year	Sugar (or Starch) Applied	Total Produce of Barley		Relative Yields (Control=100)
		Without Sugar	With Sugar	
		Lb	Lb	
1906	Spring	2,485	**	—
1907††	,,	3,578	3,249	91
1908	,,	1,820	1,404	77
1909	,,	2,563	2,261	80
1910	Autumn	2,082	2,502	120
1911	,,	1,244	1,915	154

** Very small crop, not weighed
†† Starch applied instead of sugar in 1907

Pot and laboratory experiments show that when plant residues are added to soil or sand, a vigorous decomposition of the cellulose by aerobic organisms ensues and appreciable quantities of nitrogen are assimilated from the atmosphere How far this has a bearing on the practice of green manuring and the introduction of any organic residues to the soil, is a question for closer investigation.

4 *Agricultural Value of Carbonate of Lime recovered from Causticising Plant* *By* Professor JAMES HENDRICK, *B Sc , F I C.*

Great quantities of precipitated carbonate of lime are obtained as a by-product from causticising plant In many parts of the country, at any rate, this precipitated chalk is thrown on the dump-heap as a waste product, while it may be that the surrounding fields are hungering for carbonate of lime

This waste product as obtained from the dump-heap contains about 50 per cent of moisture, and is a somewhat tenacious putty-like substance The dry matter is, as might be expected, mainly carbonate of lime. Small quantities of other substances are present, which vary considerably, according to the nature of the recovery process used A little silicate of lime is always present, and there is generally some organic matter The material is always alkaline, and sometimes strongly so The soluble matter and the alkalinity were determined in a number of samples The alkalinity is in some cases due to calcium hydrate, and in others to sodium hydrate and sodium carbonate It varies greatly in different samples In certain samples an alkalinity due to soda, and corresponding to as much as 6 per cent of sodium hydrate, was found In other samples the alkalinity was under 1 per cent expressed as sodium hydrate.

The soils of the north-east of Scotland are almost without exception poor in lime, yet this substance goes to waste, and even when offered for nothing to farmers in the wet state little use has been made of it One reason for this is that in the wet state it is difficult to spread It is, however, easily dried, when it forms a fine powder, which is easily distributed

A number of field experiments have been carried out with this carbonate of lime, in which it has been compared with other forms of lime, such as burnt lime and ground limestone The experiments have all been made on land deficient in lime and very subject to finger and toe in turnips So far as they have gone they show that whether the results are measured by increase of crop or by diminution of finger and toe disease, the precipitated carbonate of lime does at least as well as any other form of lime It has, on the whole, acted better than an equal quantity of commercial ground limestone This might be expected, as it is very much finer, and is therefore more thoroughly mixed with the soil It was found that the presence of a small percentage of sodium hydrate and sodium carbonate had no prejudicial effect on its action

5 *The Drainage of Soils practically free from Carbonate of Lime* *By* Professor JAMES HENDRICK, *B Sc , F I C*

6 *The Rate of Liberation of Hydrocyanic Acid from Linseed* *By* S H. COLLINS, *M Sc , F I C.*

A farmer considers linseed to be one of the safest cattle-foods, but the chemist has shown that linseed readily liberates hydrocyanic acid The author has attempted to measure the rate of liberation of hydrocyanic acid from linseed under conditions somewhat similar to those occurring during digestion. The rate at which hydrocyanic acid is liberated from linseed depends upon many details, but among the many causes which retard the liberation of hydrocyanic acid, the degree of acidity is pre-eminent So sensitive is the enzyme responsible

for the liberation of hydrocyanic acid, that acidity only one two-hundredth normal in strength is sufficient greatly to retard the liberation of hydrocyanic acid. Under no ordinary conditions can linseed liberate hydrocyanic acid in the acid juices of the stomach When 'mash' is used for feeding cattle, linseed is often left for a short time, sufficient to liberate much of the hydrocyanic acid contained in the glucoside of the linseed In such circumstances 'mash' might be dangerous, but the danger could be completely removed by making the 'mash' slightly acid Hay, straw, pulped roots, and many other ingredients of 'mash' contain traces of acids which would generally be sufficient to check the rate of liberation of hydrocyanic acid Hence in practice hydrocyanic acid is rarely liberated from linseed, either before or after eating

---

TUESDAY, SEPTEMBER 10

Joint Discussion with Section I on Animal Nutrition

The following Papers were read —

1 *Sheep and Cattle Feeding Experiments, to test the Value of Feeding-Stuffs* *By* WILLIAM BRUCE, *B Sc*

The experiments in the winter feeding of cattle and sheep which have been conducted under my care by the Edinburgh and East of Scotland College of Agriculture were designed with the purpose of testing feeding-stuffs and rations as used in the ordinary conditions of farm practice. The object was to secure results of immediate practical guidance to farmers rather than to establish scientific principles Exceptionally large numbers of animals have been used, and in most cases the results have been checked by repetition All the concentrated feeding-stuffs have been analysed, and in many cases also the straw and turnips

These experiments have been in progress annually since 1903 They may be enumerated as follows —

1903-1906 —A series of three trials of feeding-stuffs with 228, 132, and 192 sheep respectively.

1903-1904 —Trial of compound *versus* Bombay cotton-cake and also of intensive feeding with lots of 8 cattle

1904-1905 —Trials of decorticated cotton-cake, undecorticated Egyptian and Bombay cotton-cakes with lots of 8 cattle

1905-1906 —Trial of a limited *versus* an unlimited ration of turnips, and of 'moderate' *versus* 'heavy' feeding Four lots of 8 cattle.

1909-1910 —Trial of soya bean cake *versus* linseed-cake Four lots of 16 cattle

1910-1911 —Trial of soya-bean cake *versus* linseed-cake Two lots of 20 cattle.

1911-1912 —Trials of (1) coconut-cake, (2) wheat bran, *versus* linseed-cake Three lots of 14 cattle

The chief features of these experiments are too numerous for even brief consideration on this occasion Attention may be directed to two that are of special practical and scientific interest :—

(1) Want of agreement with the scientific method of estimating the value of ration by starch equivalents as applied by Kellner.

(2) An attempt to value one feeding-stuff in terms of another.

The Sheep-feeding Experiments

These experiments were conducted in December to March with half-bred hoggets folded on turnip land Subject to certain limitations as to the quantity of the items of the ration, each lot got as much as it would consume. An idea of the nature of the experiment may be got from a tabular statement of the first of the series

Food Consumed and Live Weight Increase produced in ninety-three days.

	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI
Concentrated Feeding-stuff given	None	Mixture of 1 part Decorticated Cotton-cake and 1 part Dried Grains	Linseed-cake	Mixture of 3 parts Wheat, 4 Decorticated Cotton-cake, and 2 parts Cotton-seed	Bombay Cotton-cake	Mixture of 1 part Bombay Cotton-cake and 1 part Dried Grains
Total roots consumed, in cwt	545½	530	541	537	532	516
Total hay consumed, in pounds	1,662	1,532	1 600	1 652	1 415	1 350
Concentrated feeding-stuffs, in pounds	—	2 400	1 819	1 885	2,122	2 457
Increase per lot, in pounds	1 040	1,391	1 461	1 252	1 379	1,366
Increase per head per week, in pounds	2 06	2 755	2 894	2 48	2 73	2 706
Cost of increase per lb *	2 63*d*	2 60*d*	2 52*d*	2 93*d*	2 39*d*	2 49*d*

* The prices of the foods being Turnips, 10*s* , hay, 3*l* , Bombay cotton-cake, 4*l* 6*s* 8*d* , dried grains, 5*l* 1*s* 8*d* , decorticated cotton-cake, 6*l* 16*s* 8*d* ; linseed-cake, 7*l* 6*s* 8*d* , wheat, 7*l* , and cotton-seed, 7*l* per ton The manurial value according to composition is deducted from these prices before reckoning the cost of production

In the second and third experiments of the series some modifications were made These will be apparent from the following tabular statement of the concentrated foods that were tested —

—	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI
1903–4. Lots of 38 sheep	Nothing	½ Decorticated cotton-cake, ½ dried grains	Linseed-cake	Mixture of 3 wheat, 4½ decorticated cotton-cake, 2 cotton-seed	Bombay cotton-cake	½ Bombay cotton-cake and ½ dried grains
1904–5 Lots of 22 sheep	,,	,,	,,	Egyptian cotton-cake	,,	
1905–6. Lots of 32 sheep	½ Bombay cotton-cake, ½ linseed cake.	½ Decorticated cotton-cake, ½ maize	,,	½ Bombay cotton-cake, ½ oats.	,,	Dried grains

The only detail that need be further noted here is the comparison of Bombay and Egyptian cotton-cakes The figures are as follows —

—	Egyptian Cotton-cake	Bombay Cotton-cake
Total roots consumed .	255½ cwt.	267½ cwt.
Total hay consumed	818 lb.	558 lb
Total concentrates consumed . .	1,697 lb.	1,699 lb.
Total L.W. increase . .	760 lb	830 lb
Increase per head per week . .	2 325 lb	2 539 lb
Net cost of food per lb. of L W.I.	2 849*d.*	2 473*d*

	Albu-minoids	Oil	Carbo-hydrates	Fibre
The Egyptian cake contained per cent	20 93	5 14	32 19	23 86
The Bombay „ „ „ „	19 00	5 44	34 99	22 27

In the results it may be noted that —

1 The mixture of wheat, cotton-seed, and decorticated cotton-cake, which was compounded to give the same analysis as the linseed-cake, was economically a failure.

2 Better results were obtained with Bombay cotton-cake than with Egyptian cotton-cake

3 The greatest progress was got always with linseed-cake

The Cattle-feeding Experiments

The correlated points in the cattle-feeding experiments may now be brought forward

In 1906 equal quantities of Bombay and Egyptian cotton-cake were fed to lots of 8 cattle

	Albu-minoids	Oil	Carbo-hydrates	Fibre
The Egyptian cake contained per cent.	22 56	4 9	32 94	21 48
The Bombay „ „ „ „	18 62	3 42	35 25	22 26

The total increase from each was the same—being 290 5 lb per head, or 2 07 lb. per head per day The Bombay cake, although a poor sample, was as productive as the Egyptian cake The results thus support my contention that the nutrients in Bombay cake are worth more than those in Egyptian cake

The 1911-12 cattle-feeding experiment is a much more definite case of non-agreement with the theory of starch equivalents Three lots of 14 bullocks of about 1,000 lb L W were fed in all respects alike, except that one got 4 lb linseed-cake, another 4 lb coconut-cake, and the third 4¾ lb wheat bran per head per day The common basal ration was 90 lb swedes, 12 lb oat straw, and 4 lb. Bombay cotton-cake The quantities of the foods under trial and the results obtained were as follows —

—	Linseed-cake	Coconut-cake	Bran
Total quantity	6,278 lb.	6,278 lb	7,420 lb
Starch equivalent per cent.	72 35	79 31	42 76
Total starch equivalent	4542	4978	3172
Total increase (14 cattle)	3,522 lb.	3,087 lb.	3,172 lb.
Increase per head per day	2 27	1 91	2 02

An Experimental Attempt to value a Feeding-stuff.

In the 1909-10 and the 1910-11 cattle-feeding experiments an attempt was made to find the value of soya-bean cake in comparison with linseed-cake. Two series of lots of cattle numbering respectively 36 animals, treated alike in other respects, received 4 lb. per head per day of each food for periods of about four months. Nearly seven tons of each feeding-stuff were consumed. The increases were as follows:

	Cwt.	qrs.	lb.	Cost per cwt.
Linseed-cake	84	1	24	37*s.* 8¼*d.*
Soya-bean cake	78	0	5	35*s.* 5½*d.*

The difference amounts to 2*s.* 3*d.* per cwt. L.W.I. in favour of soya-bean cake, or 25*s.* 3*d.* per ton of that food consumed.

The linseed-cake cost 9*l.* 5*s.*, and the soya-bean cake 6*l.* 15*s.* When the values of their manurial residues, 41*s.* and 52*s.*, are deducted, the net food costs 144*s.* and 83*s.* respectively. When 25*s.* per ton, the increased productive value of soya-bean cake obtained in the experiments, is added the relative food value of soya-bean cake becomes 108*s.* Thus the food value of soya-bean cake was three-fourths that of the linseed-cake, and the purchase value, taking linseed-cake at 9*l.* 5*s.*, would be ¾ (185*s.* – 41*s.*) + 52*s.* = 8*l.* per ton.

---

2. *The Feeding of Dairy Cows in the West of Scotland.* *By* Professor R. A. Berry, *F.I.C.*

Attention was drawn to the great diversity in the feeding of dairy cows as practised in the principal dairying districts in the West of Scotland. The feeding in (*a*) districts where cheese-making is mainly carried on, and (*b*) districts where the sale of milk and butter are the main objects, was considered from the point of view of economy in the supply and utilisation of the nutrients of the food.

Much of the information contained in the paper has been obtained through the kindness of the supervisor and secretary respectively of the Milk Records Society for Scotland. The paper was only intended as a preliminary contribution to this important subject.

---

3. *The Probable Error of Agricultural Experiments.* *By* Professor R. A. Berry, *F.I.C.*

Attention was directed to differences in the probable error calculated from pig-feeding experiments.

In an experiment carried out at the experiment station of the West of Scotland Agricultural College in 1911, in which seventy-six large white pigs were used with an average initial live weight of 77.6 lb. with sex equally divided and all fed on the same ration for fourteen weeks, the probable error of one animal was 12.1 per cent. of the live-weight increase. Calculating from the results of previous experiments extending over the years 1905–08, and choosing only those lots which were fed on the same or similar diets, numbering 102 pigs, with an average initial live weight of 97 lb., the probable error of one pig works out to 13.7 per cent. of the live-weight increase. Both sets of figures give practically normal frequency curves. The differences mean that twenty-one or twenty-seven pigs are necessary to determine with any degree of certainty a difference of 10 per cent. between different foods, and that thirty or thirty-eight pigs are required to determine a difference of 10 per cent. in either direction. These differences, though not large, point, when calculating the probable error, to the advisability of taking into account age and weight of animal at commencement of the experiment, also whether the data are from one complete experiment or from several experiments extending over a number of years.

Fifty female pigs in the latter experiment gave a probable error of 13.5 per cent. of the live-weight increase, and fifty male pigs 13.8 per cent.

Wood gives about 14 per cent. of the live-weight increase on the probable error for cattle and sheep. His method of calculation is followed here.

In connection with the variation and sampling of oat straw and using data from a hundred individual straw analyses the probable error was very great, and varied according to whether it was calculated on the percentage of nitrogen, the total weight of nitrogen, or the dry matter of individual straws, respectively. Except in the case of the total weight of nitrogen the frequency curves were abnormal Similar variations were found in the probable error and frequency curves calculated on the different constituents of the mangel

4 *Feeding Values, Practical and Scientific* *By* DAVID WILSON, *D Sc*

5 *The Investigation of Feeding for Milk Its Problems and its Method* *By* CHARLES DOUGLAS

The practical problem is the economical and profitable production of milk

This, however, cannot be fully investigated in such a way as to yield a result generally applicable, since the conditions are very various Cost of production varies with the cost of feeding stuffs, labour, and rent, and with the milking capacity of cows The value of the product alters with the price of milk at different times and places, and with the value of the manurial residues These factors must be combined in any attempt to apply practically any knowledge of the milk-producing effect of system of feeding

The scientific problem of the actual influence of foods on milk yield is separate from and subordinate to this practical issue

The essential method of investigation is the actual recording of milk-yields

Purely chemical calculations cannot be regarded as final, but are valuable chiefly as yielding hypotheses The 'scientific ration' is no more than an hypothesis; and it is one which leaves out of account essential factors, physiological and psychological which may be summarised in the phrase the individuality of the organism This is illustrated in the contrasting records of cows and in recent experiments on the influence of flavour, &c

The hypotheses must be tested by actual recorded results The necessity for this is illustrated by results recently obtained in relation to the influence of ventilation and temperature

Very large numbers of experiments and observations must be recorded in order to obtain reliable results

The extent of the necessary survey must be kept in view It is of little value to ascertain the temporary effect of a ration on milk-yield The subject of investigation must be the whole lactation, including in that term the capacity of the cow to yield milk in the succeeding lactation

In view of the extended character of this problem, sufficient investigation must be made to eliminate the influence of certain disturbing factors, such as the variations of different cows, and of cows in different lactations, and the influence of accident and season

It is necessary, in fact, to break up the problem and to investigate separately the influence of different rations on the milk-yield of cows (*a*) of various capacities and (*b*) under various conditions

6 *Note on the Use of Cotton-seed Oil as a Substitute for Butter-fat in Calf Feeding* *By* JAMES HENDRICK, *B Sc* , *F I C*

In most experiments on feeding calves with separated or skim milk and an oil in substitution for the butter-fat, cod-liver oil has been the oil used. Consequently the opinion is prevalent that this is the only oil which can properly be used The author recently carried out some experiments which were intended mainly as practical demonstrations on the economy of using separated milk and oil in substitution for whole milk in the feeding of ordinary commercial calves In these cotton-seed oil was used as well as cod-liver oil Cotton-seed oil was chosen as a comparatively cheap and easily obtained vegetable oil which is extensively used in human food, and which is known to be wholesome Another

reason why it was chosen was that it was found that practical men, even of the intelligent and educated class, had a profound suspicion of it as a food for calves This suspicion appeared to be based on the general unsuitability of cotton-cake as a food for young stock.

Three series of calves were fed during the experiments Each series consisted of three lots treated as follows —

Lot 1 Fed on whole milk till time of weaning

Lot 2 Fed on whole milk till three to five weeks old, then whole milk gradually replaced by separated milk and cod-liver oil, or by separated milk, cod-liver oil, and a meal gruel

Lot 3 Fed on whole milk till three to five weeks old, then the whole milk gradually replaced by separated milk, cotton-seed oil, and a meal gruel

After weaning, the calves were all treated similarly till about two years old, when they were sent to the butcher, fat Records of the weights were kept till the time of slaughter, when the carcase weights and a report on the carcases by the butcher were obtained

The following table gives a summary of the results —

—	Lot 1 Whole Milk	Lot 2 Cod-liver Oil	Lot 3 Cotton-seed Oil
Total number of calves	14	15	15
Average weight at start	109 lb	113 lb	107 lb
Average weight at weaning	309 lb	290 lb	280 lb
Average increase when weaned	200 lb	177 lb	173 lb
Average cost of feeding to time of weaning (per calf)	*3l* 19*s* 3*d*	1*l* 7*s*	1*l* 5*s* 9*d*
Average cost of food per pound of increase	4 82*d*	1 83*d*	1 79*d*
Average weight when sent to butcher	1,150 3 lb	1,117 lb	1,078 3 lb
Average increase when sent to butcher	1,041 3 lb	1,004 lb	971 3 lb

The table shows that there is little difference, on the average, between the increases made by calves fed with cotton-seed oil and those fed with cod-liver oil The cost of the cotton-seed oil feeding was slightly less There did seem to be a distinct difference in favour of the whole-milk calves till the time of weaning After that there was no significant difference, and at the time of slaughter the differences between the lots was so small as to be within the limits of experimental error So far as the evidence of these experiments goes it shows that cotton seed oil is as suitable as cod-liver oil as a substitute for butter-fat in feeding calves

7 *The Feeding of Cattle* *By* J Ross

Discussion.

Dr F. G. Hopkins remarked that it seemed to be characteristic of the present time for departments of scientific knowledge in which a certain sense of finality, conjoined with consequent dogmatism, had existed, to undergo revolution Such a revolution seemed to be in progress in the science of nutrition Its dogma has been that the efficiency of a dietary can be measured by its energy and protein content alone, other details being of comparatively small importance The revolution consists in the recognition of the fact that these details may be of the very greatest importance Facts recently acquired indicate that the quality, as well as the quantity, of protein must be considered, and

that the relative proportion of the non-nitrogenous constituents is by no means a matter of indifference. More recent is the recognition of the fact that constituents present in minute amount, such, for instance, as may be lost when the cortex is removed from grain, are of vital importance to the animal Something too was present in normal foodstuffs which in minute amount was absolutely necessary for growth He believed that such constituents were many, and one region of dietetics would come to be almost a branch of pharmacology The actual practical importance of these facts could only be ascertained by the combined labours of laboratory workers and of practical stock-raisers

Dr LEONARD HILL gave an account of his investigations, conducted with the co-operation of Dr Martin Flack, on the bearing of certain localised constituents from grain on the nutritive value of the food produced He described experiments in which rats and pigeons had been fed on white bread, standard bread, or wholemeal bread, and stated that the results showed that the removal of small quantities of material situated in the husk deprived the resulting white bread of the power to sustain life

Dr CATHCART referred especially to three points —

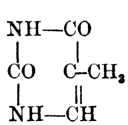
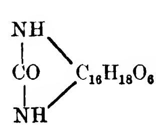
(1) *Protein minimum*.—Both quantity and quality of protein used are of importance The amount necessary depended on requirements, *i e* whether for maintenance, growth, fattening, work, etc In the heterogeneous nature of the food used lay salvation

(2) *Appetite* —Why not pay attention to the appetite of animals? An animal has its likes and dislikes as regards food well marked

(3) *Idiosyncrasy* —This is one of the most difficult of problems What value is to be laid on results of experiments on animals which show a marked divergence from the so-called normal?

Mr CASIMIR FUNK discussed the importance of certain substances in the food with special reference to the etiology of beri-beri and scurvy

It has recently been shown that the substance preventing beri-beri may be isolated from rice-polishings This substance, for which the name vitamine has been proposed, possesses probably the formula $C_{17}H_{20}N_2O_7$ and crystallises in colourless needles which melt at 233° The quantity of this substance originally obtained was small, and only a few curing experiments were performed, and a confirmation of these facts was therefore necessary With a method analogous to this, previously described, it was found possible to isolate the curative substance from other material, such as yeast, milk, and ox-brain In all these cases the substance, which cures in minute quantities, seems to be entirely identical with the substance from rice-polishings The occurrence of this substance, together with other pyrimidine bases such as uracil and thymine, its analogous properties and reactions lead to the conclusion that vitamine itself is a pyrimidine base, derivative of nucleic acid and the two-nitrogen are probably bound to form a ureid, analogous in structure to other pyrimidine bases

 (Thymine)  (Vitamine)

Only this constitution would explain the neutral reaction of the body and its characteristic properties

Besides yeast, milk, and ox-brain the anti-neuritic substance was detected in lime-juice, and is at present undergoing further investigation This substance is not identical with the anti-scorbutic substance present in lime-juice, which seems to be less stable and especially sensitive to the action of alkali Therefore, for further investigation it is necessary to obtain a method of fractionation in acid solution

A further investigation of rice-polishings led to the isolation of allantoin, this substance when given to pigeons suffering from polyneuritis was found to prolong life of the birds for several days, without, however, improving the neuritic symptoms

The nitrogenous substances hitherto detected in rice-polishings are thus vitamine, allantoin, and choline.

The present investigation of beri-beri throws an entirely new light on the physiological importance of pyrimidine and purine bodies

Dr C CROWTHER defended the attitude of the agricultural chemist in attempting to compare the nutritive value of farm foods on the basis of their chemical composition, despite the admittedly imperfect nature of present knowledge and methods of computation of nutritive values He was of opinion that the method of comparison on the basis of starch equivalents, as put forward by Kellner, might be usefully employed for practical purposes Further, that the data advanced during the discussion, when properly interpreted, were in no way conclusive in their bearing upon this point Practical feeding experiments in Denmark, conducted upon a very large scale and according to a uniform plan, had led to a scale of relative values for different foods which, with few exceptions, was almost identical with that deduced from their starch-equivalents

Professor J J R MACLEOD, Professor J HENDRICK, Dr GOODWIN, Mr J GOLDING, and Dr MILBURN continued the discussion

EVENING DISCOURSES

FRIDAY, SEPTEMBER 6

Radiations Old and New *By* Professor W H BRAGG, *F R S*

THE remarkable properties of the new rays which have been examined with such eagerness in recent years throw a curious and interesting light on the older attempts to find a satisfactory theory of radiation Newton and Huygens, Young and Fresnel discussed various theories rejecting or adopting, and each has given his reasons for his final choice It is instructive at this present time to examine those reasons, and to consider the influences which prompted them to make their great discoveries

The advances which Newton and Huygens made at the close of the seventeenth century were based in part on the discovery that the propagation of light was not instantaneous, as Des Cartes had conceived The latter philosopher supposed light to be a continuous pressure merely tending to movement, a pressure which was exerted across a plenum reaching from the luminous object to the eye Huygens was unable to conceive how the Cartesian theory could explain the mutual penetration of rays of light 'It is impossible,' he says, 'so to understand what I have been saying about two persons mutually seeing one another's eyes, or how two torches can illuminate each other '[1]

Thus Newton and Huygens introduced the idea of the motion of some sort of matter as a fundamental point in their theories They did so in different ways, and the distinction grew to be a cleavage between two schools of thought It was not a very deep distinction at first it would have been easy to have stepped from one side to the other of the dividing line Only in later times did the corpuscular and wave theories stand immovable in hostile antagonism It is not at all impossible that modern research will once more draw the two theories together

The difference may be put in this way The former imagined the light corpuscle to move from the source of light to the recipient as we should now say, the carrier of the energy remained unchanged throughout the process On the other hand, Huygens imagined the disturbance to be passed on from particle to particle of the ether, that is to say, the energy was carried by relays of particles It must be remembered that he thought of the ether as a collection of particles resembling but smaller than the particles of luminous bodies The latter particles he supposed to float in a subtle medium which agitated them and made them strike against the particles of the ether, which thus became the seat of a spreading pulse To a certain extent the difference between the ideas of Newton and Huygens might be likened to the difference between the despatch of a message by a special runner and the propagation of a rumour This would, however, scarcely go far enough, for Huygens was obliged to introduce the important notion of 'springiness' in order to develop his theory We may see how this necessity arose

There were two properties of light which seemed to Huygens to be of first-rate importance, and his first object was to shape this theory to explain them The one was the extreme speed of light which Romer had recently deduced from observations of Jupiter's satellites, the other was the way in which rays of light traversed each other without hindrance Accordingly, he rejected the idea of the transport of matter—the corpuscular theory—since he could not

[1] 'Treatise on Light,' by Christiaan Huygens, translated by Silvanus P Thompson, p 22

imagine how matter could move with so great a speed, nor could he conceive that material rays might be able to traverse each other. He arranged his ether corpuscles in a row between the source and the receiver, and compared the movement of light with the passage of a disturbance along a row of glass spheres. In this way he planned to give any desired velocity to the wave, for, as he says, there is nothing to hinder us from supposing the particles of the ether to be of a substance as nearly approaching to perfect hardness and possessing a springiness as prompt as we choose. And further, the mutual traverse could be illustrated by directing two other glass spheres against the ends of the row—with equal but opposite velocities and in the line of the row—whereupon each sphere was reflected with its original speed. The idea of springiness thus introduced was sufficient in addition to explain the fact that the velocity of light was independent of its intensity.

It is to be observed that the ideas of hardness and impenetrability are important factors in Huygens' explanations.

The difference between the ideas of Newton and Huygens develops itself in another very important direction. The theory of the former implied the transference of energy from place to place without spreading by the way. That of the latter led naturally to spreading, and indeed too much so, as it seemed to Newton, who rejected it mainly on that ground. Huygens was really unable to meet Newton's objection, for his famous construction of the wave-front as an envelope of secondary waves is rather empirical than deductive. The construction was a true one, nevertheless, and it led him to some of his most brilliant discoveries, such as his determination of the wave-front in Iceland spar.

Newton held it as one of his main objects to explain the varieties of colour. He had discovered that colour constituted an essential quality or distinction of light which could not be altered by reflection or refraction, and he had to account in some way for a variation which did not depend on the speed in space. He investigated the colours of thin sheets of transparent materials, such as soap-films, and, as is well known, he supposed that the light corpuscle went through regular successive stages of easy reflection and easy transmission, and that the length of those stages varied with the colour. In this way he introduced the idea of periodicity and the direct connection of colour with periodicity which are such important factors of the wave theory. A soap-film which was of such a thickness that red light was in a fit of easy reflection at the second face, was not related in the same way to green light, and hence the colours of the films. With colours Huygens did not concern himself. Moreover, he only considered the single pulse. The wave-train, the interference principle, and the transverse vibration were introduced by Young and Fresnel.

Let us now consider some of the properties of the rays from radioactive substances.

In the case of the α particle we have a movement of matter which belies all that Huygens conceived to be essential to its nature. The α particle is an atom, as material as anything else, and yet it travels with a speed comparable to that of light. One of the two main reasons which Huygens gave for rejecting the corpuscular theory falls at once. Moreover, as long as it moves with this excessive speed it is able to penetrate other atoms with ease, and so the second reason is greatly shaken.

These remarkable effects are worth a closer examination. The usual method of investigating the behaviour of any of the new rays is based on their electrical effects. As an α particle passes through a gas it leaves behind a trail along which are to be found certain atoms which have lost electrons, and other atoms to which the separated electrons have attached themselves. By collecting these debris from the various places where they are formed we can map out the whole path of the particle and learn its history in various circumstances. We have been able to show that the path is an almost perfectly straight line, broken only by rare deflections, and those chiefly at the end of the track when the speed is less. Such a path implies that the α particle has passed through many thousands of atoms. For it could not have pushed them all out of the way, being too light to do so, and it could not have gone round the various atoms, since it has no sense to recover a line once lost. The methods by which the properties of the α particles were first discovered are, however, somewhat

difficult to explain and illustrate to a large audience Fortunately Mr C T R Wilson has recently developed a beautiful method of rendering the tracks of the rays visible. Through his kindness I am able to illustrate my statement by photographs which he has taken His method depends upon the sudden expansion of a mass of damp air through which the rays are passing, the chill due to the expansion causes a fog deposit on the positive and negative particles in the tracks of the rays When the gas is well illuminated the tracks stand out as bright lines on a dark background, and it is easy to obtain permanent records of the effects One picture shows a number of α-ray tracks radiating from a point at which a speck of radium has been placed Another, on a larger scale, shows the end portions of one or two of the tracks, the occasional deflections, to which I have already referred, are plainly visible, and it is to be observed how straight the path lies between the sharp bends At one of the severer deflections there is a slight spur from the point of deflection, which is believed to be due to the recoil of the atom which has been the cause of the change in direction Some tracks originate in a slight enlargement, and look like pins with small heads No doubt this is also a phenomenon of recoil the atom of radium emanation has exploded in mid-air, and while the shot has gone a relatively long distance one way, the gun has leaped back a short distance in the other

Other photographs show the tracks of β-rays, which are electrons moving with speeds approaching very nearly—in some cases—to that of light The β-ray is much more liable to deflection than the α-ray, as is clearly shown. This is no doubt due to the smallness of its mass, and for much the same reason it is less effective in removing electrons from the atoms which it traverses

These new radiations make us familiar with the idea of material streams moving with velocities of the order of light, free, moreover, to traverse each other without mutual injury Thus we find that both the reasons which Huygens gave for the abandonment of a corpuscular and the adoption of a pulse theory were quite mistaken

It is true that Huygens might have objected that neither α-rays nor β-rays can show the same power of penetrating great thicknesses of matter as the light which passes through miles of atmosphere or many yards of water The utmost range in air of the swiftest α particle is less than 4 inches, and in the same medium the β-ray moves no more than a few feet

But there is a third form of ray, the γ-ray, or x-ray, which possesses the most startling powers of penetration, it can pass even through inches of steel Nor is there any reason to suppose that our discoveries have reached the limits of penetration of these rays The γ- or x-ray leaves no trail of positives and negatives behind it, and no fog settles to show where it has passed We know of its existence only through its power of originating the more obvious β-ray, and a fog-photograph of a gas through which an x-ray stream has passed shows the tracks of β-rays beginning at irregularly spaced points in the path of the x-rays and completing their rather tortuous tracks within short distances therefrom The older methods of investigation have indicated that the x-rays are separate entities, each of which has the power of originating one β-ray, and one only, handing over to it all the energy which it possesses Indeed they have gone further, and shown that one β-ray originates each x-ray, and gives to it its own energy Mr Wilson's photographs illustrate these deductions and go far to confirm them Thus the β-ray and the x-ray are interchangeable forms of carrier of the same quantum of energy carried by the former form the energy is easily deflected, by the latter it is not It is curiously reminiscent of the fits of easy reflection and transmission

Have we then in these rays the actual corpuscles which Newton imagined? Much time and labour are even now being spent in the attempt to verify or to disprove their parallelism to the rays of light; and many interesting facts have already been discovered For instance, light itself has the power of causing electrons to spring from matter upon which the light is incident, though to be sure the velocity is very much smaller than that of the β-ray. If verification is found, there will be strong reasons for supposing that Newton's corpuscular theory of light was partially correct in form

But of course the main difficulty of a corpuscular theory of light lies in the

need to explain the periodicity which is so marked a feature and is partially responsible for the effects of diffraction. It is this consequence of the wave theory which was so brilliantly developed by Young and Fresnel, and which must form an essential part of any explanation of the radiation process. While we feel that we may have been hasty in neglecting altogether the form and the ideas of the corpuscular theory, we must somehow contrive to retain the positions which the wave theory has won for us.

It is curious to reflect that Newton rejected the pulse theory for wrong reasons, and Huygens the corpuscular theory for reasons also mistaken. It is even more curious to consider how little their mistakes affected their work. Their theories were no more to these men than familiar and useful tools. Much of the heated argument in which we occasionally indulge arises from the failure to recognise that hypotheses are in the first instance made for personal use. We really have no justification for demanding that others shall adopt the means which we find most convenient in the modelling of our own ideas.

MONDAY, SEPTEMBER 9.

Modern Problems relating to the Antiquity of Man.

By ARTHUR KEITH, *M.D., LL.D.*

ON my bookshelves there is placed a series of odd volumes containing past Reports of this Association which Fortune sent my way many years ago on a Whitechapel bookstall. Among them there is one volume I prize—that which contains the history of the meeting at Aberdeen in 1859. In that volume you will find an early phase of the subject of my discourse for this evening—the Antiquity of Man. Sir Charles Lyell presided over the Section of Geology; in his opening address he announced that 'a work will very shortly appear by Mr. Charles Darwin—the result of twenty years' observation and experiment,' and that the evidence which had accumulated in recent years 'made it probable that man was old enough to have co-existed at least with the Siberian Mammoth.' From other statements made in his address it is clear that Lyell was then convinced that man's appearance on earth was infinitely older than the limits fixed by Biblical record. I do not suppose I have a single listener who heard that address in Aberdeen 53 years ago, but even those who are not yet old will concede that the new doctrine, even as preached by Sir Charles Lyell, was not likely to be acceptable to the general membership of the Geological Section in the year 1859. You will find an exact record of what happened at the meeting not in the official report of the year, but in the letters of Mr. William Pengelly, the explorer of Kent's Cavern. Orthodoxy was represented at the meeting by the Rev. Dr. Anderson, who, in Mr. Pengelly's words, 'attempted to castigate Lyell for his opening address. There was a considerable amount of orthodoxy in the room, and Dr. Anderson got a very undue share of applause.' The doctrine which Lyell and his companions championed in the face of public opprobrium in 1859 is the accepted and orthodox opinion of the vast majority of thoughtful people in the year 1912.

That splendid movement of the nineteenth century, which knocked the shackles of tradition from the problem of man's origin, was led by men of courage, conviction, and sound judgment. It was a progressive and victorious movement they initiated; but in every movement of that kind there comes a time when those who cleared the way turn circumspect, cautious, and more critical than constructive. Opinion tends to become fixed and conventionalised, and then a new heterodoxy raises its head. That is the phase which we, who make a special study of the facts relating to man's origin, seem to have reached now. I cannot cite a more stalwart or distinguished representative of the orthodox opinion of to-day than Professor Boyd Dawkins, of Manchester. In his Huxley Lecture of 1910 he gives very clearly his opinions on the antiquity of man—ripe convictions which are founded on a lifetime of active investigation and study. In his opinion the history of man does not extend beyond the Pleistocene period—the phase of the earth's history which immediately precedes the one in which

we live. He accepts the fossil man of Java—*Pithecanthropus*, a being with a brain a little more than half the size of a modern man's—as representative of mankind at the beginning of the Pleistocene; before the end of that period men of the modern type appeared. In Professor Boyd Dawkins' opinion, then, man was evolved during the Pleistocene period and therefore, from a geologist's point of view, is a recent addition to the earth's fauna. If we ask how long ago it is since man appeared, Professor Boyd Dawkins replies: 'It cannot be measured in years—only by the sequence of geological events, and by the changes in animal life.' Yet we are certain that years came cycling round in the Pleistocene period just as they do now, and that every cycle wrought some degree of change on the face of the earth and on the form of living things—a degree of change which may be imperceptible in the period of a man's life, and yet cumulative and apparent in the course of time. Men who have studied the transformations effected during the Pleistocene period have formed varying estimates of its duration, but we may safely adopt as a moderate figure the 400,000 years given by Professor Sollas at a meeting of this Association in 1900. We may accept, then, as the orthodox opinion of to-day that the dawn of the very earliest form of humanity lies 400,000 years behind us; in that space of time man, as we know him now, was evolved from a crude, almost pre-human form.

For a representative of modern heterodoxy—as far as relates to the antiquity of man—we cannot do better than visit the Royal Natural History Museum in Brussels and follow the guidance of M. Rutot, who has devoted himself to the study of the stone implements of ancient man and of recent geological formations. One civilisation succeeded another in Pleistocene as in historical times. You will admit, when you examine the handiwork of the men of the Magdalenian age—at the close of the Pleistocene—that our ancestors were then artistic and skilled workmen. As we pass backwards in time from the Magdalenian to the Solutrean, and from the Solutrean to the Mousterian, Mousterian to Acheulean, and Acheulean to the Chellean—thus passing well beyond the mid-point of the Pleistocene—that although the handiwork of man changes in form and in design it does not lose in skill of execution; those flints of the remote Chellean period assure us that man had then a capable brain and a skilled hand. When, however, M. Rutot proceeds to show us the implements which were fashioned by men in the earlier parts of the Pleistocene, it is very probable that our orthodox companions will pull out their watches and find they have pressing engagements elsewhere. Human workmanship becomes cruder as we approach the commencement of the Pleistocene. The stones which have been wrought by man's hand (Eoliths) become then more difficult to distinguish from those which have been shaped by natural forces. M. Rutot, however, is convinced that he has traced man, by means of his eolithic culture, not only to the commencement of the Pleistocene, but into and through the two long geological periods which preceded the Pleistocene—the Pliocene and Miocene—and even well into the formations of the still older period, the Oligocene. In M. Rutot's opinion the origin of mankind must be assigned to a time as early as the Oligocene period. Professor Sollas has made a provisional estimate of 900,000 years for the Pliocene, and 1,800,000 for the Miocene. On this crude estimate the heterodox opinion as to the antiquity of man must be placed at over 3,000,000 years. It is only just to M. Rutot to state that he would by no means agree to the estimates given by Professor Sollas. In his opinion the duration of the Pleistocene period was not more than 139,000 years.

The modern heterodox movement, which I have sought to bring before you in the person of M. Rutot, had as its pioneer the late Professor Prestwich—a geologist whose long experience and great knowledge was tempered with a sound and conservative judgment. In 1859 he found flints on the uplands of Kent, between the Thames and the Weald, which he recognised as certainly the handiwork of man. Thousands of these eoliths have been collected by Mr. Benjamin Harrison. The deposits in which these eoliths are found were assigned by Professor Prestwich to a Pliocene date. Fifty years ago Sir Charles Lyell expressed the opinion that 'sign's of man's existence' would be found in the Cromer beds of East Anglia, which mark the commencement of the Pleistocene period in England. Eoliths have been found not only in the Cromer beds, but also in the Pliocene formations of that district—in the Norwich crags by Mr.

Clarke, and under the Red Crag by my friend Mr Reid Moir Thus in England heterodox opinion traces man to the commencement of the Pliocene period. I need only add that eoliths, as evidence of man's existence, are rejected by many whose opinion is entitled to our respect The usually accepted opinion, then, is that man makes his appearance in a definitely human form about the commencement of the Pleistocene period; there are also those who refer his evolution to a much earlier period of geological history.

One thing is certain, whatever period is adopted, the time must be long enough to allow mankind to be distributed and differentiated as we now see it in the world of to-day Modern human races, white and yellow, red, black, or brown, although so different on the surface, are yet so similar in their structure and constitution that we must suppose all of them to have arisen from a common stock Let us look at the problem in a concrete form I will take as opposite and contrasted types of modern humanity the fair-haired, white-skinned, round-headed European and the woolly-haired, black-skinned negro of Central Africa, and set them side by side and study them from a purely zoological point of view We must admit that both are highly specialised types, neither represents the ancestral form Now, in seeking for the ancestral form of our breeds of dogs, of horses, or of cattle, we select one of a generalised and ancient type—such as we conceive might have been modified to produce modern breeds We must apply the same system to human races If we search the present world for the type of man who is most likely to serve as a common ancestor for both negro and European we find the nearest approach to the object of our search in the aboriginal Australian He is an ancient and generalised type of humanity, he is not the direct ancestor of either negro or European, but he has apparently retained to a greater degree than any other living race the characters of that common stock from which both European and negro arose If, then, we accept the Australian native as the nearest approach to the common ancestor of modern mankind—and it must be admitted that it is not a low form of man we are postulating as a common ancestor—can we form any conception of the length of time which would be required to produce the African and the European from this common stock? What do we know of the rate at which mankind evolves? There is the classical instance of Egypt During his residence in that country Professor Elliot Smith and his colleagues—Dr Wood Jones and Dr Derry—had opportunities of examining the remains of Egyptians belonging to every period—from pre-dynastic times to the present day They had thus facilities for studying the evolution of a people over a period of at least 6,000 years—probably longer They found evidence of an infiltration of foreign blood both from the north and from the south, they noted minor alterations in the configuration of the head and in the state of the teeth and jaws, but they could not say that the men at the end of that period were in any respect a higher or more specialised type than the inhabitants of the Nile Valley at the beginning of that period There is no need to go beyond our own country to find evidence that the evolution of man proceeds at a slow rate We have now material enough to form a fairly accurate conception of the physical condition of the people who lived in Britain these 4,000 years past. Were the prehistoric Britons to come amongst us now, dressed in our modern garb, they would pass unnoticed as fellow-citizens The Neolithic men of France, Switzerland, and Germany were not in anywise a lower race than their successors of to-day When we pass to examine human remains belonging to more remote periods we are confirmed in our belief that the evolution of human races is a slow process In this country there have been found at Galley Hill, at Bury St Edmunds, and at Ipswich human remains which belong at least to the middle part of the Pleistocene period These remains indicate a kind of man somewhat different from ourselves, but yet of the same type In size of brain and in complete adaptation to an upright posture they cannot be described as less highly evolved than we are Such evidence as we have, then, leads us to believe that the evolution of a new and distinct variety of mankind requires an extremely long period of time

If we again ask · How long will it take to evolve the African on the one hand and the European on the other from a common stock—Australoid we suppose in form?—it is very apparent, on our present knowledge, we must make a very considerable allowance of time My own opinion is that the whole length

of the Pleistocene—a period we shall say of 400,000 years—is not more than sufficient I am thus postulating in order to explain the differentiation and distribution of modern races, that mankind, at the beginning of the Pleistocene period, had reached a physical condition which has its best modern representation in the aborigines of Australia

Is it not possible, however, that the evolution of man's body may not be a story of slow, continuous, almost imperceptible change, but one of alternate spurt and quiescence? The human body is notoriously the subject of sport, of defects and malformations Many of you will recall the book which Professor Bateson published eighteen years ago, entitled 'Material for the Study of Variation' The work contained many facts which seemed to indicate that the animal body was subject to violent structural changes, and that a new form of being might be produced almost at a bound We often see men in whom there is an extra vertebra in the loins, an additional rib, or a supernumerary digit, but we now recognise that these marked structural changes are merely the extreme manifestations of a normal degree of variation of which every man's body is the subject The bodies of men and anthropoids are notoriously liable to anatomical variation, and we are justified for that reason in regarding their bodies as particularly plastic material in the hands of evolution When, however, we come to examine the anatomical differences which separate one race of men from another we see that racial characters comprise, not those marked variations which so frequently are seen by the students of human anatomy, but a multitude of minor structural features such as might slowly accumulate in the course of the differentiation of one race from another When one comes to realise the extremely complex structure and finely adjusted nature of the human brain, it becomes very apparent that any addition to the most essential structure of the human body must be the result of an extremely slow process of growth Only one line of evidence shakes our belief in the slow rate of human evolution, and that is the study of certain diseases of growth to which man is liable We have come to realise in recent years that we are, as regards face, figure, stature, and nature, largely what our internal glands and secretions have made us Growth itself is definitely regulated by means of substances set free by certain glands of the body We are absolutely certain that a marked disturbance of these glands will, in the course of a few years, definitely transfigure the individual to which they belong Nature seems to have at her command a means for executing rapid advances, but when we survey what we know of man's past history and mark the changes he is subject to in the present we see no sign of her having resorted to such a means

There is another route by which we may approach the problem of man's antiquity Man does not stand alone he has distant and rather despised relations—the great anthropoid apes Although the structural hiatus between him and them is wide, yet when we compare the two types we see that there is a multitude of resemblances, so intimate and so peculiar that we cannot explain them except by supposing that man and the great anthropoids had a common ancestor at one stage of the earth's history The great anthropoids have also a distant and primitive living relative—the gibbon The gibbon in turn, while foreshadowing in his body the structural peculiarities of his more august relatives, finds his cousins by descent in more lowly forms still—the monkeys of the Old World and the monkeys of the New Of these two groups the monkeys of the New World are the nearest to the original stock which gave rise to the higher Primates It was through such a lineage that man rose to reach his present estate If, then, we are to ascertain the approximate date or, to put it in other words, the possible date at which man appeared, we must first search for the earliest traces of the basal form of the higher Primates which lead towards the human line The earliest traces we have discovered as yet were described by Dr. Max Schlosser only two years ago In the very oldest Oligocene formation of the Fayoum, Egypt, the teeth and jaws of three Primates were discovered. Two of these are allied to the South American apes, the other is a forerunner of the gibbons These Fayoum fossils are of the highest importance to the solution of our problem Their discovery assures us that at such an early date in the evolution of mammals the South American apes and the pro-gibbons were already in existence They are highly evolved forms and it is not unlikely that they appeared at a much earlier date In European strata of the period following

the Oligocene—the Miocene—many teeth and jaws of a form of gibbon, which differ only in slight and trivial details from the teeth of living gibbons, have been discovered during the past fifty years Here, then, we have the assurance that an animal which springs closely from the stock which gives rise to man has come down to us with but little change through the leagues of time marked by the Miocene, Pliocene, and Pleistocene formations By the middle of the Miocene we know the great anthropoids were in existence, it is most unlikely that the traces we have discovered mark their first appearance With the evolution of the great anthropoids the appearance of a human ancestry as a separate stock is possible From every point of view it is most probable that the human stock became differentiated at the same time as the great anthropoids On the evidence afforded by our very imperfect knowledge of fossil forms of apes we are justified in assuming that a very primitive form of man may have come into existence during the Miocene period, at the very latest during the early part of the Pliocene Thus, when we pursue the question of man's antiquity by studying the forms of Primates contained in the Tertiary strata, we find reason to extend the possible date of his origin at least a geological epoch beyond what is allowed by the strictly orthodox We are unable, however, to find evidence in support of the more extravagant claims of the ultra-heterodox represented by M Rutot

There is still another and a very important line of evidence bearing on the antiquity of man We have, in the most cursory manner, followed the evolution of various ancestral forms of ape and anthropoid from the past towards the present, I propose now to follow the history of man's evolution, so far as we yet know it, from the present into the geological past We are all evolutionists nowadays, and it is but natural that everyone of us should expect man to become more anthropoid and more brutal the further we trace him into the past What have we found? At the close of the Pleistocene period, which even orthodox and conservative geologists admit to have come to an end some 15,000 years ago, the men of Europe in stature and in size of brain were at least our equals In tooth, limb, and bone they were more robust When, however, we turn our eyes to France and pass backwards in the Pleistocene to the epoch marked by the last or fourth of the cold cycles which subdivided that period, modern man disappears, his place is taken by a human being of an altogether different kind—a human race or species to which the name of Neanderthal has been given by international consent During the last six years, thanks to the enthusiasm, industry, and genius of French anthropologists, the remains of four individuals of this race have been unearthed The strata in which these remains were found contain stone implements of the type known as Mousterian and remains of animals belonging to a cold climate Neanderthal man appears suddenly in this later part of the Pleistocene, and as suddenly disappears, to be replaced by modern man It is impossible to conceive that, just at the close of the Pleistocene period, Neanderthal man was suddenly converted into modern man Think for a minute of the interpretation you would give of the Australian strata that are being laid down now The older deposits contain the remains of aborigines, the newer, Europeans You do not suppose that the aborigines are suddenly transformed to Europeans You must apply the same interpretation to the human remains found in the later Pleistocene There was a supersession, not a transformation of races We must infer, then, that at the end of the Pleistocene period there were two distinct races of mankind—Neanderthal and modern That is a fact which our French colleagues seem to grasp with difficulty

To follow the history of modern man into the past we shall return to England It is a mystery why Neanderthal remains have not been discovered in England, they ought to be found, and a rumour is now current that they have been found The oldest remains so far unearthed in England all belong to the modern type of man They take us a long way further into the Pleistocene than the era of Neanderthal man The skull fragment, known as the Bury St Edmunds, was found in strata containing Acheulean flints and remains of the Mammoth, the 90-foot terrace of the Thames, in which the Galley Hill man was found, contains flints of the Chellean type The Acheulean and Chellean flint civilisations are attributed by Professor Boule—a most reliable authority—to the long temperate interval which lies between the last two of the glacial cycles of the Pleistocene, or, if we accept the evidence of Professor Penck, between the second and third

cycles If Mr Reid Moir and I are right in regarding the human remains lately found at Ipswich as resting under a bed of undisturbed chalky boulder-clay—it is right to say that our inferences are contested—then we have carried the history of modern man a step still further back in the Pleistocene period, for the chalky boulder-clay is the product of the great cold cycle which preceded the Chellean industry So far as the evidence in England goes it indicates the existence of a modern type of man at least as far back as the middle of the Pleistocene period.

All we know of man in Europe near the beginning of the Pleistocene is the famous lower jaw found near Heidelberg in 1907 A complete lower jaw with its full complement of teeth can tell with certainty a great deal about the individual to which it belonged There is not a shadow of doubt that the Heidelberg man belonged to the Neanderthal type, perhaps he may best be described as pre-Neanderthaloid, for in strength and massiveness of jaw he foreshadows the Neanderthal men whose remains are found in Europe towards the end of the Pleistocene Of the Neanderthal race in the middle phases of the Pleistocene we have, so far, discovered no trace Although in many features Neanderthal man shows resemblances to the anthropoids, in others he is highly specialised The teeth of an Australian native make a nearer approach to the anthropoid condition than those of Neanderthal man

We have knowledge of another fossil man belonging to the beginning of the Pleistocene In 1891 Dr Eugène Dubois discovered in Java the fossil remains of a man who, in stature, posture, and gait must have been very similar to us, but so unlike us in head form that his discoverer named this new form of man Pithecanthropus The size of his brain (855 cubic centimetres) was little more than half the size of the brain of a well-developed modern man The Neanderthal man described by Professor Boule had a cranial capacity of 1,600 or 1,625 cubic centimetres It is usual to accept the fossil man of Java as representative of his time and race, but if we do we have to suppose that in the early part of the Pleistocene, within a comparatively short space of time, the human brain developed at an astounding and almost incredible rate I leave the matter there, simply asking my audience to keep in mind that there did exist in the Far East at the beginning of the Pleistocene, or perhaps close of the Pliocene, a very low form of primitive man

Thus we have a knowledge—a very imperfect knowledge—of only two human individuals near the beginning of the Pleistocene period The one was brutal in aspect, the other certainly low in intellect It is hard, then, to believe that in strata belonging to the period preceding the Pleistocene there could be found fossil remains of a man of quite a high and modern type Yet the details relating to the discovery of human remains by Professor Ragazzoni in early Pliocene strata of North Italy are so circumstantial and supported that one cannot place them lightly aside In 1860 Professor Ragazzoni was searching in undisturbed Pliocene strata for fossil shells, he discovered remains of a human skull His discovery was received with derision Between 1860 and 1880 he found in the same strata remains of three further individuals The only living anthropologist authority, so far as I can learn, who accepts Ragazzoni's discovery as authentic is the celebrated Italian anthropologist—Professor Sergi, of Rome If the remains found in these strata had been of a primitive type their authenticity would never have been called in question, but as they represented individuals as highly evolved as we are the easiest solution of the problem was to suppose that by some means these remains had been interpolated in ancient strata at a later date

Is it, then, possible that a human being, shaped and endowed as we are, may have existed so early as the Pliocene period? If we accept as authentic all the evidence brought forward by those who have traced man backwards by means of flints which have the appearance of man's work on them, then we must admit that Pliocene man is possible, for stones, apparently artificially fashioned, have been found in strata as old as the Eocene If, on the other hand, we examine the evidence relating to that group of animals to which man belongs—the Higher Primates—the facts, so far as we know them, render the existence of man in the Eocene and Oligocene periods impossible, improbable in the Miocene period, but quite possible in the Pliocene If, finally, we take into consideration all the

evidence relating to fossil forms of man, we must confess that the antiquity of the modern form of man is still an open problem. I, for one, am convinced that we have followed him almost unchanged to at least the middle of the Pleistocene, when we find him accompanied by another form of man almost as distinct from him as the gorilla is from the chimpanzee. Still further back, at the beginning of the Pleistocene, we find at least two forms of men—the pre-Neanderthaloid of Heidelberg and the small-brained man of Java—but the representatives of modern man at this early period we do not know. It does seem to me, taking all the scraps of evidence at our disposal, the slow rate of human evolution and the great blanks in the geological record into account, that a man as high as the Australoid of to-day was then in existence, but I cannot bring myself to believe that human individuals as highly evolved as those discovered by Professor Ragazzoni were in existence at an early part of the Pliocene period.

The problem of man's antiquity is not yet solved. The picture I wish to leave in your minds is that in the distant past there was not one kind but a number of very different kinds of men in existence, all of which have become extinct except that branch which has given origin to modern man. On the imperfect knowledge at present at our disposal it seems highly probable that man as we know him now took on his human characters near the beginning of the Pliocene period. How long ago that is must be measured, as Professor Boyd Dawkins insists, by the changes which the earth and living things have undergone, and yet it is only human to try to find a means of measuring that period in a term of years, and the estimates at hand give an antiquity of at least a million and a half of years.

APPENDIX I.

Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (*Chairman*), Mr. W. P. D. STEBBING (*Secretary*), Rev. J. O. BEVAN, Sir EDWARD BRABROOK, Dr. J. G. GARSON, Principal E. H. GRIFFITHS, Dr. A. C. HADDON, Mr. T. V. HOLMES, Mr. J. HOPKINSON, Mr. A. L. LEWIS, Mr. F. W. RUDLER, Rev. T. R. R. STEBBING, *and the* PRESIDENT *and* GENERAL OFFICERS. (*Drawn up by the Secretary.*)

THE Committee beg leave to recommend that the Ipswich and District Field Club, the Prehistoric Society of East Anglia, and the University of Durham Philosophical Society be placed on the list of Affiliated Societies. They also desire to report, as an example of the internationalisation of science, that the Instituts Solvay, a society, with its headquarters at Brussels, for the study of sociology, has asked for affiliation. This request, owing to the constitution of the British Association, it has been impossible to grant.

The membership of the Warrington Field Club still remains below fifty, but as it seems to continue to do good work the Committee recommend its continuance on the list of Associated Societies for another year.

The Committee desire to record that the hour for meeting of the Conference of Delegates has been changed from 3 P.M. to 2 P.M.

Professor F. O. Bower has promised to preside at the Conference of Delegates at Dundee, and to deliver an Address on Sir Joseph Hooker.

Miss A. Lorrain Smith will communicate the results obtained by the British Mycological Society from the sending out of a circular on certain Fungoid Pests. Mr. A. R. Horwood, of Leicester, will also submit a preliminary report of the Selborne Society's Committee for the State Protection of Wild Plants.

The Corresponding Societies Committee recommend the following subject for discussion, which has been suggested by Mr. Wilfred Mark Webb, of the Selborne Society: 'The Brent Valley Bird Sanctuary: An Experiment in Bird Protection.' Mr. A. Newlands, of the Inverness Scientific Society and Field Club, also will open a discussion on Water Power and Industrial Development in the Scottish Highlands.

The Committee ask to be reappointed and, in consideration of the special labour involved in its work during each year, apply for a grant of 25*l*.

Report of the Conference of Delegates of Corresponding Societies held at Dundee, September 5 and 10, 1912

Chairman .	Professor F O Bower
Vice-Chairman	H W T Wager
Secretary .	W P D Stebbing

FIRST MEETING, *September 5*

The Chairman, in answer to questions relating to the proper recognition of the Conference, put it to the meeting that the names of the delegates and the subjects of the papers for discussion should be printed in the day's JOURNAL, as was already done in the cases of the Committees of the Sections and the sectional papers This was approved

Mr Oke, the Rev T R R Stebbing Mr Balfour Browne, and Mr Mark Sykes having spoken on other matters relating to a more thorough recognition of the Conference, it was also agreed that a list of the delegates of the various Societies represented at the British Association meetings, with their attendances, should be printed in the Report of the Conference

The Secretary read the Report of the Corresponding Societies Committee It was agreed that a grant of 25*l* should be applied for at the meeting of the Committee of Recommendations On the proposal of Dr J G Garson, it was agreed that the Conference should nominate a second representative to attend the Committee On Mr Mark Webb's proposal, it was decided that the Secretary should be the second representative (These motions have since been proved to be out of order, the Rules of the Association only allowing the Conference to nominate one member on the Committee of Recommendations)

The Chairman then delivered his Address, entitled —

The Life and Work of Sir Joseph Hooker, O M , F R S [1]

He said that the death of Sir Joseph Hooker, in December 1911, might be held to have been one of the most outstanding events of the year He did not give any consecutive biographical sketch of this great botanist, but indicated the various lines of activity in which he excelled He contemplated him as a traveller and geographer, as a geologist, as a morphologist, as an administrator, as a scientific systematist, and, above all, as a philosophical biologist

As a traveller Sir Joseph visited all the great circumpolar areas of the Southern Hemisphere He spent almost four years in India He botanised in Palestine and in Morocco, and finally in the Western States of America The results he worked up into such great publications as 'The Antarctic Flora' and 'The Flora of British India '

As an administrator Hooker guided for thirty years the destinies of Kew Gardens, and served for five years as President of the Royal Society As a systematist he co-operated in the Genera Plantarum and the Kew Index But it was as a philosophical biologist that he rose to the greatest heights An early friend of Darwin, he was the first to accept his views In 1859 Darwin himself wrote 'As yet I know only one believer, but I look at him as of the greatest authority—viz , Hooker ' While Lyell wavered, and Huxley had not yet come in, Hooker was in 1859 a complete adherent to the doctrine of the mutability of species

This position was confirmed by a masterly series of essays from Hooker's pen The most notable was the introduction to the 'Flora of Tasmania ' The last was that great address to the Geographical Section of the British Association at York in 1881 on 'The Geographical Distribution of Organic Beings ' It was such works as these which led to the cumulative result that he was universally held to have been the most distinguished botanist of his time

[1] Printed in full in the *Makers of British Botany*, Cambridge University Press, 1912

Sir Edward Brabrook (Balham and District Antiquarian and N H Society) proposed, on behalf of the Conference, a vote of thanks to the Chairman His subject was most appropriate, and was a most eloquent and valuable study It suitably gave point to the famous opening—Let us now speak of great men

Professor M C Potter (Durham University Philosophical Society), in seconding the vote, thought that the meeting would regard the Address as a most stimulating account of one of the greatest of the great scientific minds of the nineteenth century

Miss A Lorrain Smith reported on the results obtained by the British Mycological Society from the sending out of a circular on certain fungoid pests She said that, following on a suggestion by Mr Harold Wager, a committee of the Society had been formed to draw up a series of questions which might afford direction and guidance to members of local Natural History Societies in their study of fungi It was felt that workers living in the country had many opportunities of making careful observations and collecting specimens which would be of service to research students The questions submitted had reference mainly to diseases of fruit and forest trees, about which data were urgently desired The questions were as follows —

1 The very serious disease known as 'Silver-leaf' (so called because the leaves become of a silvery colour), which affects fruit-trees, particularly the Victoria plum, is now thought to be caused probably by *Stereum purpureum*, the sporophores of which appear on the dead wood of the affected trees Observations on the following points would be valuable

 (*a*) The distribution of *Stereum purpureum* as a *parasite* or *saprophyte* in the district
 (*b*) *The habitat*, with exact identification of the dead tree, shrub, or wood on which the sporophores are found
 (*c*) Did 'silvery' foliage occur on the tree or shrub previous to the occurrence of the sporophores on the dead wood?

2 Many British trees are greatly injured by the growth of fungi belonging to the Polyporaceæ Information is wanted as to —

 (*a*) The name of the trees affected, and
 (*b*) The name of the Polypore causing the injury

3 A revision of the British Clavariaceæ is being made by Mr A E Cotton, F L S, of The Herbarium, Royal Gardens, Kew, who would be much obliged if members of local Natural History Societies would forward to him at the above address specimens of this order for identification and examination

The committee of her Society also asked the secretaries of the local Natural History Societies to inform them as to the number of their members interested in the study of mycology, and if any lists of fungi or papers thereon had been published by them The questions were sent to over 100 secretaries of societies Miss Smith was disappointed to record that so far only four had acknowledged them No further response had been received, although the subjects on which information was needed were not minute in size She explained, however, that the fungus season was over before the circular was issued, and that possibly the subject would be taken up in the coming autumn months

As a result of the discussion the delegates present undertook to lay the matter before their societies, and, so far as possible, to induce their members to co-operate with the British Mycological Society

Mr H N Davies (Somersetshire Archæological and Natural History Society) asked that copies of the questions should be sent to delegates as well as to the secretaries of the societies His Society seemed not to have received the paper, and he wondered if those which were not exclusively Natural History Societies had been overlooked

Mr Harold Wager thought the questions put by the British Mycological Society were very suitable for investigation by the local societies, and he hoped that the delegates present would be able to induce their members to take up these and similar problems for investigation As showing what valuable work

can be done, it is worthy of notice that the Mycological Committee of the Yorkshire Naturalists' Union has during the last twenty-seven years published no less than 178 reports, papers, and notes on British fungi, especially on those found in Yorkshire, and has recorded nearly three thousand species (2,895 up to March 1912) from the county, of which a considerable number are new to Britain, and many of them new to science The published papers and reports deal mainly with the systematic determination of species, but papers on economic topics, and on the structure and life-histories of fungi, are also included In addition, a bibliography of fungi of the North of England and a valuable and well-arranged fungus flora of Yorkshire have also been published. There can be no doubt that substantial additions to our knowledge of fungi and of problems connected with them can be made by local societies, and it is hoped that the suggestions brought forward by Miss Lorrain Smith will not be lost sight of by the societies represented at this Conference, the members of which. he felt sure, are all anxious to do some real work for the advancement of science

Sir George Fordham (Hertfordshire N H Society and Field Club) wished to deal with a larger question than that specifically dealt with by the communication He pointed out that certain plant diseases—the American Gooseberry Mildew in particular—were obtaining a very serious and destructive prevalence, and were being dealt with by the local authorities under orders made by the Board of Agriculture and Fisheries, and he thought it was very evident that more and more of such diseases as are injurious to agriculture would be scheduled Of course, for such work expert officials exist, and others will be appointed and paid, but he considered it of great importance that public opinion and public knowledge should be cultivated extensively, and that investigations as to the extent of the prevalence of injurious diseases of this character should be also carried on by local societies Such action would be welcomed by County Councils and otherwise would be of great assistance in dealing with diseases and insect pests

The delegates of the Glasgow N H Society and the Perthshire Society of Natural Science and the Chairman also joined in the discussion

The State Protection of Wild Plants

Mr A R Horwood (Leicester Museum) submitted the following preliminary report of the Selborne Society's Committee for considering this subject In Mr Horwood's absence the Report was read by the Secretary

From time to time efforts have been made to draw attention to the necessity of protecting and preserving our native flora At the present time, however, the energy spent upon the question is entirely inadequate, and the results so far have not been commensurate with the efforts put forth It is the object of this communication to report progress and to make a further appeal for help and co-operation

The Selborne Society, whose object has always been to preserve Nature in all aspects, has recently established a section of which Dr A B Rendle is chairman, and the writer recorder This small association so far represents the only organised body endeavouring to bring about State protection Professor G S Boulger, a member of this section, who was instrumental in forming it, has a draft of the Bill it is intended to introduce already framed

The section has endeavoured to forward this national question in three principal ways —

1 By educating the public as to its need (by leaflets, notices, articles, &c)
2 By obtaining co-operation in the prevention of destructive agencies
3 By endeavouring to obtain permanent interest and help in all parts of the country for the canvassing of all sections of the public at the right moment to make an appeal that cannot be put aside

By aid of the County Councils the schools of this country have each received leaflets and cards deprecating wholesale extirpation of wild flowers, and suggesting the proper way and time to collect them

It is now proposed to obtain the assistance of County Councils in the framing

of bye-laws preventing hawking, &c, along highways in every county The Rural District Councils are asked also to prevent the evil effects of road trimming and scraping upon wayside flowers, if only from the æsthetic standpoint The secretaries of scientific societies and associations are asked to form a local branch by appointing corresponding secretaries to keep the section in touch with local needs, and to afford all the help that such a widely organised basis for propaganda supplies This appeal in advance will reach many to whom otherwise the section would not have had access

The Rev F Smith (Prehistoric Society of East Anglia) affirmed that nurserymen and people who traffic in rare specimens and varieties are the great exterminators of plants in many localities Cases of the kind had come to his notice during the past thirty-five years in Scotland He considered that the British Association should make a point of helping in the protection of wild plants He also felt that schoolchildren ought not to be sent about the country to collect plants to be used in their schools—a procedure too common with teachers

Mr Wilson L Fox (Royal Cornwall Polytechnic Society) supported the observations of the previous speaker He mentioned that in a book by the Rev C A Johns, entitled 'A Week at the Lizard' the *habitat* of several rare plants and ferns is mentioned, of which that district is now practically depleted, owing to the ravages of local dealers He had heard of hampers of more or less rarities having been sent off to collectors and others, for which a sum of as much as 5*l* had been paid for one consignment As an instance, the Royal Fern (*Osmunda regalis*), once common in many valleys in Cornwall, is now seldom met with except in private grounds In this way the Cornish chough has become practically extinct, through the eggs being sold, he had been informed, for 1*l* or more apiece, notwithstanding that it is protected under the Wild Birds Protection Act He feared legislation, though it might be useful to a certain extent, was not a sufficient deterrent in cases where rare specimens could command a commercial value An efficient remedy was needed He suggested that perhaps the most effectual one would be to have plant and fern sanctuaries, or at least gardens set apart in different localities, where under proper cultivation and suitable conditions every rare British species might be preserved in one situation or another to prevent its extermination

Mr E A Martin (South-Eastern Union of Scientific Societies) said that the question as to the means to be taken to preserve plants would require careful consideration He was strongly opposed to parliamentary action Laws were not made to manufacture criminals, and to think that children who gathered amongst common flowers a few rarer ones should come under the purview of the law was abhorrent At the same time he thought that greater care should be taken by those in charge of children to prevent plants from being promiscuously uprooted, and where only two or three of a species were found none should be plucked An Act of Parliament would do little good and much harm What was wanted was a better feeling amongst teachers toward Nature, and the great remedy is education in that direction

Mr R M Wilson (for Essex Field Club) supported the remarks made as to the extirpation of plants, and gave as an illustration meeting a man on Ben More, in Perthshire, carrying a hamper of rare ferns gathered in the vicinity These ferns he proposed sending to a nurseryman in Glasgow to whom he had sent other consignments, and for which he had received payment, and produced a postal order for 15*s*. This man had Moore's book on British Ferns, and visited all the localities specified therein in his search

Mrs White (School Nature-Study Union) said that her Society had a membership of fifteen hundred teachers, and that the committee of her Society had already considered this subject They were doing all they could to impress upon teachers the necessity of teaching Nature-study with the least possible destruction of the common flowers and with the complete preservation of the rarer plants

At a later point in the discussion on this subject, Mrs White suggested the insertion of an article, putting forward the views of the Conference of Delegates, in the Journal of the Union This was published five times yearly, and was edited by Miss von Wyss, of the London Day Training College It would reach about two thousand teachers The meeting being in agreement with the sugges-

tion, Mrs White, on being applied to, said that she would be pleased to send an article on the lines suggested for insertion in the Journal

Mr H N Davies (Somersetshire Archæological and Natural History Society) said that flowers which had almost totally disappeared were the Single Pæony from the Steep Holm in the Bristol Channel, and the Cheddar Pink and *Lithospermum cœruleum* from the Cheddar Cliffs and the Mendips Lovers of wild-flowers are guilty of collecting these rare plants and planting them in their gardens, and some nurserymen are verily guilty of transplanting them and cultivating them for sale It is a difficult question whether rare plants and their localities should be brought prominently before children, as it might stimulate them to mischief

After some further discussion, it was proposed by Mr H D Acland (Royal Institution of Cornwall), and seconded by Sir George Fordham 'That this Conference of Delegates from the Affiliated and Associated Societies requests the Council of the British Association to consider what would be the best means of preventing the extinction of rare animals, birds, fishes, and plants in the United Kingdom, and to take such steps as they consider best'

The Chairman remarked, in conclusion, that the discussion amply justified the existence of such a Conference as the present He doubted whether by any direct action or by legislation any effective check could be imposed He saw in education the best preventive Rarity does not make a specimen more effective as a medium for teaching He had taught more students on specimens of *Caltha palustris* than on any other species He was heartily in agreement with the suggestion that a list of *common* species suitable for teaching in schools should be drawn up and circulated, so as to divert the attention of pupils and teachers from the rarer plants

SECOND MEETING, *September* 10

The first business before the meeting was the movement of a vote of sympathy on the death of the Rev R Ashington Bullen, at one time Secretary of the South Eastern Union of Scientific Societies, and delegate from the Union to the Conference of Delegates The vote was proposed by the Rev T R R Stebbing, who bore testimony to the love in which Mr Bullen was held, and the unobtrusive way in which he did good His sudden death was a shock to all who had ever had anything to do with him Mr E A Martin also added a few words of sympathy, referring to the energy Mr Bullen put into everything he undertook

Mr G Claridge Druce (Ashmolean Natural History Society of Oxfordshire) brought before the meeting the following resolution, which, as amended, ran — 'That this meeting of delegates cordially approve of the objects of the Society recently established for the purpose of obtaining areas containing interesting specimens of flora and fauna, and also objects of geological interest' Mr Druce said that the resolution was of some importance at that moment, as the Society had commenced operations by acquiring about two thousand acres of shingle and saltings at Blakeney, in Norfolk, the breeding-ground and *habitat* of many interesting species of birds and plants It was the intention eventually to hand over the area to the National Trust

Mr A H Garstang (Southport Literary and Philosophical Society), speaking on the resolution, said that Canon Rawnsley suggested the formation of a Government department or the appointment of a Government official whose province it should be to generally superintend the preservation of places such as the National Trust was formed to protect, and to whom the Trust could appeal in case of emergency to veto its conversion to purely commercial uses without adequate restrictions As the kind of places this proposal might have in view might naturally include those reserved for the preservation of local fauna and plant life, his suggestion was, that if any such proposal took shape, the delegates might exert a powerful influence in supporting it

Mr W Whitaker (Essex Field Club), in the absence of Sir Daniel Morris, seconded the resolution, which was carried unanimously.

Mr H N Davies, speaking as a delegate for the first time, put forward the following suggestions as to means of making the Conferences of greater use —

1 The provision of a lounge where delegates might meet each other, and compare notes, and so obtain mutual help.

2 Each delegate to bring a copy of the annual volume of his Society to be placed on the lounge-room table

3 Each delegate to be furnished with the agenda of the meeting a day or two before it takes place

4 A social gathering of delegates (supper, conversazione, &c) to be a feature of the annual meeting of the British Association

5 Any other means which can be suggested to make the Conferences really helpful

The above proposals led to a lively discussion, during which it was pointed out that the Conference stood on altogether a different plane from the Sections, that every delegate was largely interested in one or other of the Sections, that the time of the members during the week of the meeting was already fully occupied, and that as the delegates were all members of the Association they could not expect special advantages in the way of rooms which other members of the Association had not got The matter was also carried a step further by Mr Whitaker pointing out that any changes in the arrangements of the Conference could only be brought before the Council through the Corresponding Societies Committee, on which sat as *ex-officio* members the President and officers of the Association Mr A H Garstang thereupon proposed —'That it be a recommendation to the Corresponding Societies Committee to form a committee of the delegates themselves to discuss during the provincial meetings questions of administration and the proper application of their energies which suggest themselves during the meetings of the Conference' This was seconded and carried

Mr Harold Peake (Anthropological Section) brought the following matters before the Conference from the committee of his Section —

1 That material illustrating the folk-lore of the British Isles was much desired, especially from the Scotch districts All information on this subject to be addressed to Miss Charlotte Burne, c/o The Folk-Lore Society (5 Terrace Gardens, Kensington, London, W)

2 Evidence was also required as to the distribution throughout the British Isles of implements dating from the early part of the Bronze Age especially flat celts Information on this subject to be sent to Mr. Peake, Westbrook House, Newbury

Through the kindness of the Selborne Society Mr Wilfred Mark Webb read the following paper, which was illustrated by a series of slides from photographs taken in the sanctuary

The Brent Valley Bird Sanctuary—An Experiment in Bird Protection By WILFRED MARK WEBB, *F L S , F R M S , Honorary Secretary of the Selborne Society*

The difficulties of administering the Wild Birds Protection Act are well known, but it is possible for individuals and societies with a little trouble to do something towards preserving birds, and it is an experiment in this direction which I am going to describe

Some eight or nine years ago it was suggested, at a committee meeting of the Brent Valley branch of the Selborne Society, that some steps might be taken to protect the nightingales which were known to nest in a wood of about nineteen acres lying between Ealing and Harrow, which comes within the boundary of the London Postal District A small sub-committee of three members, of whom I happened to be one, was appointed to make arrangements, if possible, for the wood to be watched in the nesting season

As a result, it became part of the duties of a farm-hand to attend to warn off bird-catchers and bird's nesting boys After a year, however, the committee took over the wood, employed a watcher of their own, and kept up the hedges with their own hands But though success was attained in other directions, the nightingales were not heard for several seasons—in fact, not until the appointment of the present keeper, who is engaged all the year round, and takes a particular interest in his work.

I may say now that the wood is composed of oak trees, with coppice below, chiefly consisting of hazels, though there are many other trees and shrubs represented, and these have grown to a considerable size in places that have not been regularly cut for many years

Among the common birds that build as a rule are the song-thrush, missel-thrush, blackbird, and hedge-sparrow, but there are often special points of interest concerning even them with regard, for instance, to the material of the nests, its position, and variations of the eggs

As a rule, too, from the beginning there have been each year a chiffchaff's nest and several willow-warblers' The garden-warbler and whitethroat always breed, and so does the lesser whitethroat, while the turtle dove builds every year We have only once followed the development of the young cuckoo, though the eggs were found in the wood before it was protected We have had on one occasion a wild duck's nest, but the parent birds were most probably shot outside the confines of the wood

The long-tailed tit at one time was common, and it is almost the only bird that has not increased its numbers The wren is numerous, and builds in the open or under cover in empty tins or old kettles which may or may not have been put up for the purpose The robin is another bird which has the habit of making its nest sometimes in natural and sometimes in artificial surroundings

It is noticeable, however, that with the exception of an occasional pair of blue-tits, one of which nested in a hollow branch, none of the birds which commonly build in holes, except the two already mentioned, were found to nest. This, no doubt, was owing to the fact that the oak trees in the wood are young and sound

At the beginning of one season, however, my boy took it into his head to make some rough nesting-boxes with large openings, and that summer nests were recorded of the flycatcher, the great tit, and the tree-sparrow Then other boxes were made with various-sized openings, and of more careful construction. These succeeded marvellously well Blue-tits and coal-tits built, the tree-sparrows and great tits increased in number, and the wrens and robins made use of the boxes as well as of the tins and kettles The nuthatch made its appearance, and has been a resident in the wood ever since Experiments were also made in the way of open boxes for flycatchers, while trays for blackbirds and thrushes, which were fastened to the trees, found favour with some birds, in spite of the almost unlimited possibilities for their building in the undergrowth. Some of the visitors, whom we admitted sparingly in those days, asked us to make nesting boxes for them The reputation of these dwellings spread, and as we were only too anxious to retain the services of our custodian we were glad to be able to keep him busy in the winter, and the profits on the boxes went towards the expenses of the wood It soon became evident that improvements could be made in the nesting boxes For gardens also it might be advisable to have something a little less artificial-looking The only boxes on the market made from natural logs with which we were acquainted were those designed by Baron Berlepsch

To these we found several objections —

(1) First of all, they were manufactured in Germany

(2) The idea of making them harmonise with their surroundings was not carried through, because there was a piece of ordinary wood screwed on the top of the log

(3) The lid could not be lifted off at any time for the contents to be examined, and considerable trouble had to be spent in unscrewing it in order to clean out the boxes at the end of the season

(4) The inside, which was cut out very carefully to imitate the hole bored by a woodpecker, did not provide much room in the smaller-sized boxes for large broods, and all the trouble was thrown away in the case of all those which were fastened low down on the trees for the smaller birds I therefore spent some amount of time and trouble, with the help of a member who has a joinery works, in producing boxes suited to our requirements, and these have been very successful We made very rigorous tests last year, with which we were quite satisfied

We find also that the opening of the box at the top instead of at the front does not disturb the birds if they happen to be sitting. A great deal more pleasure is therefore given to those who put up the boxes. The eggs and young can also be seen more easily, and quite good Nature-study observations can be made, in which case even the commonest birds are useful.

We have not forgotten that birds like the woodpecker and the wryneck make no nest, and if their eggs are to be kept together for hatching a flat-bottomed box is useless. The bottoms of all the boxes are slightly curved, but special cup-shaped bases are put into those which are fastened high in the trees. We make special large openings for robins, and restrict the size where only birds useful to the gardener are to be encouraged. It is useful to bear in mind that the common sparrow and starling seldom build low down.

I might call attention to the fact that a small series of boxes is on view in the Zoological collection arranged at this meeting of the British Association, Section D (Zoology).

In addition to the birds that nest, we have a number that always seem to be present, but whose eggs we have not found. The list includes three species of woodpecker, and the brown owl, which up to the present has refused all the nesting sites put up for its benefit. The barn-owl is often to be seen, as is the golden-crested wren. The nightjar has been present during three seasons, the kingfisher is a common visitor, and jays and magpies occasionally appear.

Snipe sometimes frequent the outskirts of the wood, and on one occasion I found a dead woodcock within its boundary. This bird my wife had apparently seen alive a few days previously. Recent records include the breeding of the goldfinch, redpoll, marsh-tit, and wryneck.

It will be noted, however, that very few of these birds are really rare, but it is the object of the committee to protect those which occur near London. In the Brent Valley there are few crops that the birds are likely to damage, but in other localities it might have to be borne in mind when doing similar work that certain species should not be unduly encouraged, or, indeed, given protection.

It is practically impossible to describe all the pleasure that can be obtained from such a reserve. It is a source of interest all the year round, and the mammals, reptiles, insects, and other creatures should be taken into consideration. The mice are somewhat destructive to eggs, but the way in which they utilise old birds' nests is worthy of attention. The fungi may be mentioned, and a bird reserve also becomes a sanctuary for flowering plants. Steps will be taken to form committees in other parts of the country, and I should be very pleased to give any advice that I can to those who are thinking of protecting any definite areas in the way which has been outlined.

Mr. A. Newlands (Inverness Scientific Society and Field Club) afterwards read a valuable technical paper, of which the following is an abstract:—

Water Power and Industrial Development in the Scottish Highlands.

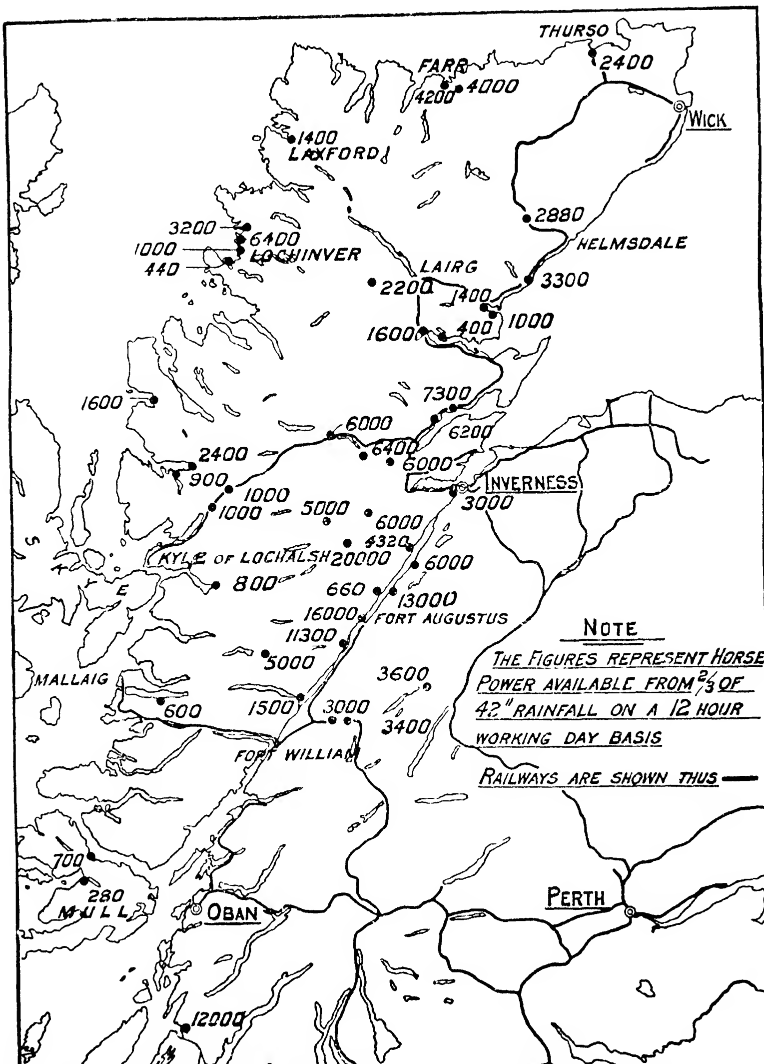
Its high mountain ranges, its lochs fed from large drainage areas, its rainfall ranging from sixty to one hundred inches per annum on the high altitudes, and its steep and rapid rivers are the natural features of the Highlands of Scotland which give to that region a character unique in the British Isles. It is these characteristics which pre-eminently mark it out as possessing possibilities for hydro-electric development nowhere else available in Great Britain.

Further, it has the advantage, from the standpoint of transport facilities, of possessing an indented and well-sheltered coastline, and it is well served by good roads and railways. Its climate is equable, and it has sturdy and industrious country populations available for any industrial development. A start has been made at Kinlochleven and Foyers, where the British Aluminium Company already generates 30,000 and 7,000 horse-power respectively, and there are many smaller installations.

The accompanying map—in no sense complete—shows the processes available from certain drainage areas, it being contended that only by developing the energy available from each drainage drill, and generating current of the same

periodicity in each of them so that they can be linked up and can feed each other as required, can maximum efficiency and economy be attained

The present-day method of generating electric energy in bulk in power-stations and of distributing and selling it over a wide area as required opens up



tremendous possibilities for areas similar to the Highlands, and development of such areas is rapidly taking place all over the world

The congestion consequent upon the centralisation of industry and the increasing cost of coal as a source of power are both to-day providing the stimulus for hydro-electric development

Our infant industries were all planted and grew up round the steam engine,

which had its birth 120 years ago Owing to their dependence on coal, the districts where it was available became our great industrial centres, particularly if sea or other transport facilities were also there available

With the growth of industry these centres became increasingly congested until to-day this congestion is largely responsible for the unrest and expense which is so marked a feature of our industrial life

Decentralisation or an industrial development in rural or country districts is the most probable solution, and regions like the Highlands of Scotland possessed of possibilities for cheap power and convenient transport facilities to and from a world-wide market have first claim on any such development These Highland water powers are estimated at one million horse-power in amount, but if the figure be put at 500,000 horse-power, it is equivalent to the power which could be generated from three and a half million tons of coal, which at 10*s* per ton represents a yearly value of 1,750,000*l* These powers should be looked upon as a national asset, and should be developed by Government assistance and control, on the same lines as light-railway projects and other works for the public benefit are assisted

In this way the lean years which would have to be faced until the power demand grew to an extent sufficient to pay interest on capital would be tided over and success then assured, for it is an axiom in all hydro-electric schemes that the power demand is never stationary but goes on increasing year by year

In addition to the previous business there was also before the meeting a proposal by Dr A Loir, of Havre (Delegate to the British Association from the French Association meeting at Havre in 1914), regarding a meeting of the Conference of Delegates at Havre in 1914 on the occasion of the meeting of the British Association in Australia The proposal was favourably received, and it was decided that it should be officially discussed at the meeting of the Conference at Birmingham during the ensuing year

The Conference closed with votes of thanks to the readers of the papers and to the Chairman for presiding

The following Delegates attended the Conference and signed the attendance book, their attendance being indicated by the figures 1 2, which refer respectively to the first and second meeting

AFFILIATED SOCIETIES

2	Andersonian Naturalists' Society	M A B Gilmour, F Z S
2	Ashmolean Natural History Society of Oxfordshire	G Claridge Druce, M A
1	Belfast Naturalists' Field Club	F Balfour Browne, M A
1	Berwickshire Naturalists' Club	G P Hughes, J P
1	Birmingham and Midland Institute Scientific Society	C J Watson
1 2	Birmingham Natural History and Philosophical Society	Dr W Elliott
1	Brighton and Hove Natural History and Philosophical Society	Alfred W Oke, F G S
1	British Mycological Society	Miss A Lorrain Smith
1	Buchan Club	J F Tocher, B Sc
1	Cardiff Naturalists' Society	Prof A Trow, D Sc
1	Cornwall, Royal Institution of	H D Acland, F G S
1	Cornwall Royal Polytechnic Society	W L Fox
1 2	Croydon Natural History and Scientific Society	Bryan Corcoran
1 2	East Anglia, Prehistoric Society of	Rev F Smith
1 2	Edinburgh Geological Society	R C Millar
1 2	Edinburgh Field Naturalists' and Microscopical Society	R C Millar
1 2	Essex Field Club	J Wilson
1 2	Glasgow Natural History Society	Peter Ewing, F L S
1 2	Glasgow Royal Philosophical Society	Prof Bower, F R.S
1	Hampshire Field Club and Archæological Society	W. Dale, F.S A.

1 2	Hertfordshire Natural History Society and Field Club . . .	Sir George Fordham.
1	Hull Geological Society	T Sheppard, F G S
1	Hull Scientific and Field Naturalists' Club	T Sheppard, F G S
1	Institution of Mining Engineers .	Dr J S Haldane, F R S
1 2	Isle of Man Natural History and Antiquarian Society	Rev J Davidson
1 2	Liverpool Geographical Society	Nathaniel Caine
2	Liverpool Geological Society	J H Milton, F G S
1	Midland Institute of Engineers	Dr J S Haldane, F R S
1 2	London Selborne Society	W M Webb, F L S
1	Manchester Geographical Society	J Howard Reid, F R G S
1 2	Manchester Microscopical Society	Mark L Sykes
1 2	Manchester Geological and Mining Society	William Watts, M Inst C E
1 2	Norfolk and Norwich Naturalists' Society	Robert Gurney
1 2	Perthshire Society of Natural Science	William Barclay
1 2	Rochdale Literary and Scientific Society	J R Ashworth, D Sc
1 2	Sheffield Naturalists' Club	Wm Paikin, F R M S
1 2	Somersetshire Archæological and Natural History Society	H N Davies, F G S
1 2	South-Eastern Union of Scientific Societies	E A Martin, F G S
2	Southport Literary and Philosophical Society	A H Garstang
1	Worcestershire Naturalists' Club	John Humphreys, F L S
1	Yorkshire Naturalists' Society	T. Sheppard, F G S

ASSOCIATED SOCIETIES

1 2	Balham and District Antiquarian and Natural History Society	Sir Edward Brabrook, C.B
1 2	Bradford Natural History and Microscopical Society	W West, F L S
1	Ealing Scientific and Microscopical Society	Dr W Deane Butcher
1	Grimsby and District Antiquarian and Naturalists' Society	Dr O T Olsen, F L S
1 2	Hampstead Scientific Society	R W Wylie, M A
1	Hastings and St Leonards Natural History Society	Thomas Parkin, M A
1	Hawick Archæological Society	C J Wilson
2	Inverness Scientific Society and Field Club	A Newlands
1 2	Leeds Naturalists' Club and Scientific Association	Harold Wager, F R S
2	Lewisham Antiquarian Society	Sir Edward Brabrook, C B.
1 2	School Nature Study Union	Mrs White, D Sc

The Corresponding Societies of the British Association for 1912–1913.

Affiliated Societies

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Royal Technical College, Glasgow R Barnett Johnstone and Harry G Cumming	263	2s 6d	2s 6d	Annals, occasionally
Ashmolean Natural History Society of Oxfordshire, 1828	Miss A L Stone, 2 St Margaret's Road, Oxford	300	None	5s	Report, annually
Belfast Natural History and Philosophical Society, 1821	Museum, College Square Robert Patterson F L S	200	None	1l 1s	Report and Proceedings annually
Belfast Naturalists' Field Club, 1862	A W Stelfox Scottish Temperance Buildings Donegall Square South Belfast	393	5s	5s	Report and Proceedings, annually
Berwickshire Naturalists' Club, 1831	Rev J J M L Aiken, B D, Manse of Ayton, Berwickshire	400	10s	7s 6d	History of the Berwickshire Naturalists' Club, annually
Birmingham and Midland Institute Scientific Society, 1859	Alfred Cresswell, Birmingham and Midland Institute, Paradise Street, Birmingham	133	None	10s 6d and 5s	Records of Meteorological Observations, annually
Birmingham Natural History and Philosophical Society, 1858	Avebury House Newhall Street, Birmingham W H Foxall F R G S	194	None	1l 1s	Proceedings, occasionally
Bournemouth Natural Science Society, 1903	Theo Michell, Trewirgie, 37 Christchurch Road, Bournemouth	407	None	10s	Proceedings, annually
Brighton and Hove Natural History and Philosophical Society, 1854	J Colbatch Clark, 9 Marlborough Place, Brighton	1 0	None	10s	Report, annually
Bristol Naturalists' Society, 1862	W D Henderson, The University Bristol	135	5s	10s and 5s	Proceedings annually
British Mycological Society, 1896	Carleton Rea, 34 Foregate Street, Worcester	106	None	10s	Transactions, annually
Buchan Club, 1887	J F Tocher B Sc, 5 Chapel Street, Peterhead	180	5s	5s	Transactions, annually
Burton-on-Trent Natural History and Archæological Society, 1876	G S Hollister, F G S Iverleigh, Scalpcliffe Road, Burton on-Trent	220	None	5s	Report, annually, Transactions, occasionally
Canada, Royal Astronomical Society of, 1884	Canadian Institute Building, Toronto J R Collins	560	None	2 dollars	Journal, bi-monthly
Caradoc and Severn Valley Field Club, 1893	H E Forrest, 37 Castle Street, Shrewsbury	210	5s	5s	Transactions and Record of Bare Facts, annually
Cardiff Naturalists' Society, 1867	Dr Owen L Rhys 26 Windsor Place, Cardiff	500	None	12s 6d	Transactions, annually
Chester Society of Natural Science, Literature, and Art, 1871	Grosvenor Museum, Chester G P Miln	1,007	None	5s and 2s 6d	Report, annually Proceedings, occasionally
Cornwall, Royal Geological Society of, 1814	The Museum Public Buildings, Penzance John B Cornish	84	None	1l 1s	Transactions, annually
Cornwall, Royal Institution of, 1818	George Penrose, F L S County Museum Truro	198	None	1l 1s	Journal, annually
Cornwall, Royal Polytechnic Society 1833	E W Newton, 4 Cross Street, Camborne Cornwall	400	None	10s upwards	Report, annually
Cotteswold Naturalists' Field Club 1846	L Richardson, 10 Oxford Parade Cheltenham	110	1l	15s	Proceedings annually
Croydon Natural History and Scientific Society, 1870	Public Hall, Croydon P M Roberts	127	None	10s, 5s, and 2s 6d	Proceedings and Transactions annually
Dorset Natural History and Antiquarian Field Club, 1875	Rev Herbert Pentin, M A, M R A S, Milton Abbey Vicarage, Dorset	400	10s	10s	Proceedings, annually
Dublin Naturalists' Field Club, 1885	R Southern, B Sc 3 Kildare Place, and T Halley, B A, 14 Hume Street, Dublin	123	5s.	5s	'Irish Naturalist,' monthly Report, annually

Affiliated Societies—continued

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	G W Shirley, Ewart Public Library, Dumfries	435	None	5*s*	Transactions and Proceedings, annually
Durham, University of, Philosophical Society, 1896	J W Bullerwell and T H Havelock, Armstrong College, Newcastle on Tyne	200	None	10*s*	Proceedings, half yearly
East Anglia, Prehistoric Society of, 1908	W G Clarke, 12 St Philip's Road, Norwich	140	None	5*s*	Proceedings, annually
East Kent Scientific and Natural History Society, 1857	A Lander, 17 High Street, Canterbury	76	None	10*s* and 5*s*	Transactions, annually
Eastbourne Natural History, Scientific, and Literary Society, 1867	Richard Gilbert, 5 Orchard Road, Eastbourne	110	2*s* 6*d*	5*s*	Transactions, biennially
Edinburgh Field Naturalists' and Microscopical Society, 1869	Allan A Pinkerton, 19 Shandwick Place, Edinburgh	214	None	5*s*	Transactions, annually
Edinburgh Geological Society, 1834	India Buildings, Edinburgh David Gloag	243	10*s* 6*d*	12*s* 6*d*	Transactions, annually
Elgin and Morayshire Literary and Scientific Association, 1836	H B Mackintosh, Redhythe, Elgin	158	None	5*s*	Transactions, occasionally
Essex Field Club, 1880	Essex Museum of Natural History, Romford Road, Stratford W Cole and B G Cole	300	None	15*s*	'Essex Naturalist,' quarterly, 'Year-book,' annually, 'Special Memoirs,' &c, occasionally
Glasgow, Geological Society of, 1858	Peter Macnair, F R S E, 207 Bath Street, Glasgow	300	None	10*s*	Transactions and Proceedings, annually.
Glasgow, Natural History Society of, 1851	Alex Ross, 409 Great Western Road, Glasgow	265	None	7*s* 6*d*	'Glasgow Naturalist, quarterly
Glasgow, Royal Philosophical Society of, 1802	Prof Peter Bennett, 207 Bath Street Glasgow	1,000	1*l* 1*s*	1*l* 1*s*	Proceedings annually
Hampshire Field Club and Archæological Society, 1885	W Dale, F S A, F G S, The Lawn, Archer's Road, Southampton	250	5*s*	10*s* 6*d*	Proceedings, annually
Hertfordshire Natural History Society and Field Club, 1875	Charles Oldham, Kelvin, Berkhamsted, and E J Salisbury, Limbrick Hall, Harpenden	141	None	10*s*	Transactions, annually
Holmesdale Natural History Club, 1857	Miss M C Crosfield, Undercroft, Reigate	76	None	10*s* and 5*s*	Proceedings, occasionally
Hull Geological Society, 1887	J W Stather, F G S Newland Park Hull	70	None	5*s*	Transactions, occasionally
Hull Scientific and Field Naturalists' Club, 1886	T Stainforth, B A, The Museum, Hull	131	None	5*s*	Transactions, annually
Institution of Mining Engineers, 1889	Percy Strzelecki, 39 Victoria Street, London S W	3,400	None	None	Transactions, monthly
Ireland, Statistical and Social Inquiry Society of, 1847	W Lawson, Dr N M Falkiner, and Herbert Wood, 6 Eustace Street, Dublin	90	None	1*l*	Journal, annually
Leeds Geological Association, 1873	F Hawkesworth, Cross Gates, Leeds	126	None	5*s*	Transactions, occasionally
Leicester Literary and Philosophical Society, 1835	Corporation Museum C H Spencer, 50 Knighton Drive, Leicester	289 Membs & Associates	None	Members 1*l* 1*s*, Associates 10*s* 6*d*	Transactions annually
Lincolnshire Naturalists' Union, 1893	Arthur Smith, F L S, City and County Museum, Lincoln	112	None	5*s*	Transactions, annually
Liverpool Biological Society, 1886	J A Clubb, D Sc, Free Public Museum, Liverpool	80	10*s* 6*d*	1*l* 1*s*	Proceedings and Transactions, annually
Liverpool Botanical Society, 1906	A A Dallman, F C S, 63 Sea View Road, Wallasey, Cheshire	130	None	5*s*	Proceedings, annually, Transactions, occasionally

Liverpool Engineering Society, 1875	T R Wilton, M A, 1 Crosshall Street, Liverpool	570	None	1l 1s, 10s 6d, and 5s	Transactions and Report, annually
Liverpool Geographical Society, 1891	William Smith, 14 Hargreave's Buildings, Liverpool	500	None	Members 1l 1s, Associates 10s 6d	Transactions and Report, annually
Liverpool Geological Society 1858	Royal Institution W A Whitehead, B Sc	94	None	10s 6d	Proceedings annually
London Quekett Microscopical Club, 1865	W B Stokes 4 Winn Road, Lee, S E	420	None	10s	Journal, half-yearly
London Selborne Society, 1885	42 Bloomsbury Square, W C W M Webb, F L S	3,050	None	5s	'Selborne Magazine,' monthly
Man, Isle of, Natural History and Antiquarian Society, 1879	P M C Kermode, Glen Aldyn, Ramsey, Isle of Man	235	2s 6d	7s 6d and 5s	Proceedings, twice a year, Transactions, occasionally
Manchester Geographical Society, 1884	J Howard Reed and E Steinthal, 16 St Mary's Parsonage, Manchester	680	None	Members 1l 1s, Associates 10s 6d	Journal, quarterly
Manchester Geological and Mining Society, 1838	5 John Dalton Street, Manchester Sydney A Smith	350	None	2l 2s, 1l 5s, and 1l	Transactions of Inst of Mining Engineers, monthly
Manchester Microscopical Society, 1880	Frederick Dishley, 14 Westwood Street, Moss Side, Manchester	181	5s	6s	Transactions and Report, annually
Manchester Statistical Society, 1833	Herbert Heape and F Vernon Hansford, 3 York Street, Manchester	171	10s 6d	10s 6d	Transactions, annually
Marlborough College Natural History Society, 1864	E Meyrick, F R.S, Marlborough College	300	1s 6d	3s and 5s	Report, annually
Midland Counties Institution of Engineers, 1871	G Alfred Lewis, M A, Albert Street, Derby	385	1l 1s	2l 2s and 1l	Transactions of Institution of Mining Engineers, monthly
Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	L T O'Shea, The University, Sheffield	306	None	1l 10s	Transactions of Inst of Mining Engineers, monthly
Norfolk and Norwich Naturalists' Society, 1869	S H Long, M D, 37 St Giles Street, Norwich	290	None	6s	Transactions, annually
North of England Institute of Mining and Mechanical Engineers, 1852	Neville Hall, Newcastle-upon-Tyne Lawrence Austin	1,342	None	25s and 42s	Transactions of Inst of Mining Engineers, monthly
North Staffordshire Field Club, 1865	W Wells Bladen, Stone, Staffs	666	5s	5s	Report and Transactions, annually
Northamptonshire Natural History Society and Field Club, 1876	H N Dixon, M A, 17 St Matthew's Parade, Northampton	215	None	10s	Journal, quarterly
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of, 1829	Hancock Museum, Newcastle-on-Tyne C E Robson and J A Richardson	420	None	21s	Transactions, annually
Nottingham Naturalists' Society, 1852	Prof J W Carr, M A, University College, Nottingham	150	2s 6d	5s	Report and Transactions, annually
Paisley Philosophical Institution, 1808	J Gardner, 3 County Place, Paisley	547	5s	7s 6d	Report and Meteorological Observations, annually
Perthshire Society of Natural Science, 1867	Tay Street, Perth S T Ellison	363	2s 6d	5s 6d	Transactions and Proceedings, annually
Rochdale Literary and Scientific Society, 1878	J Reginald Ashworth, D.Sc, 105 Freehold Street, Rochdale	146	None	6s	Transactions biennially
Rochester Naturalists' Club, 1878	John Hepworth, Linden House, Rochester	15	None	5s	'Rochester Naturalist,' quarterly
Sheffield Naturalists' Club, 1870	C Bradshaw, Public Museum, and C J Hardy, 31 Hampton Road, Sheffield	109	None	5s	Report, bi-annually Proceedings occasionally
Somersetshire Archæological and Natural History Society, 1849	The Castle Taunton Rev F W Weaver, Rev E H B Harbin, and O Tite	86	10s 6d	10s 6d	Proceedings annually
South Africa, Royal Society of, 1906	G M Clark, South African Museum, Cape Town	207	None	2l	Transactions, occasionally

Affiliated Societies—continued

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
South-Eastern Union of Scientific Societies, 1896	W Martin, LL D, 2 Garden Court, Temple, E C	59 Societies	None	Minimum 5*s*	'South-Eastern Naturalist,' annually
Southport Literary and Philosophical Society	A H Garstang, 82 Forest Road, Southport	17	None	7*s* 6*d*	Proceedings, occasionally
South Staffordshire and Warwickshire Institute of Mining Engineers, 1867	G D Smith, 3 Newhall Street, Birmingham	150	1*l* 1*s* and 10*s* 6*d*	42*s* and 21*s*	Transactions of Institution of Mining Engineers, monthly
Torquay Natural History Society, 1844	Major E V Elwes, The Museum, Torquay	180	10*s* 6*d*	1*l* 1*s*	Journal, annually
Tyneside Geographical Society, 1887	Geographical Institute, St Mary's Place, Newcastle-on-Tyne Herbert Shaw, B A	800	None	21*s* and 10*s*	Journal quarterly
Vale of Derwent Naturalists' Field Club, 1887	J E Patterson, Mossgiel, Rowlands Gill, R S O	160	None	2*s* 6*d*	Transactions, occasionally
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Museum, Warwick C West, Cross Cheaping, Coventry	70	2*s* 6*d*	5*s*	Proceedings, annually
Woolhope Naturalists' Field Club, 1851	Woolhope Club Room, Free Library, Hereford T Hutchinson	225	10*s*	10*s*	Transactions, occasionally.
Worcestershire Naturalists' Club, 1847	Education Offices, Worcester F T Spackman, F G S	170	10*s*	5*s*	Transactions, annually
Yorkshire Geological Society, 1837	Cosmo Johns, Burngrove, Pitsmoor Road, Sheffield	200	None	13*s*	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	The Museum, Hull T Sheppard, F G S	431 and 3,301 Associates	None	10*s* 6*d*	Transactions, annually, 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Museum, York C E Elmhirst	450	None	2*l* and 1*l*	Report, annually.

Associated Societies

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Balham and District Antiquarian and Natural History Society, 1897	A L Barron, Clophill, Wallington, Surrey	75	None	5*s*	Report, annually, Papers, occasionally
Barrow Naturalists' Field Club and Literary and Scientific Association, 1876	W L Page, 5 Cavendish Street, Barrow	278	None	5*s* and 2*s* 6*d*	Report and Proceedings, annually
Battersea Field Club, 1894	Public Library, Lavender Hill, Battersea, S W Miss L B Morris	65	2*s* 6*d*	3*s* 6*d*	—
Bradford Natural History and Microscopical Society, 1875	Fred Jowett, 2 Vincent Street, Bradford	8	1*s*	4*s*	Report, annually
Bradford Scientific Association, 1875	W Newbould, 34 Burnett Avenue, Bradford	205	None	5*s* and 2*s* 6*d*	Bradford Scientific Journal, quarterly.
Catford and District Natural History Society, 1897	W H Griffin, 40 Blythe Vale, Catford, S E	84	None	5*s*	—
Dover Sciences Society, 1879	C E Dall, B Sc, 26 Beaconsfield Avenue, Dover	49	None	6*s*	Report, annually
Dunfermline Naturalists' Society, 1902	Robert Somerville, B Sc, 38 Cameron Street, Dunfermline	156	None	5*s*	—

Ealing Scientific and Microscopical Society, 1877	F. McNeil Rushforth, Coley Lodge, 21 Florence Road, Ealing, W	169	None	10s and 2s 6d	Report and Transactions, annually
Grimsby and District Antiquarian and Naturalists' Society, 1896	The Museum, Grimsby A Bullock	81	None	4s	——
Halifax Scientific Society, 1874	J H Lumb, 32 Undercliffe Terrace, Halifax	137	None	2s 6d	——
Hampstead Scientific Society, 1899	C O Bartrum, B Sc, and R W Wylie, M A, 32 Willoughby Road, Hampstead, N W	327	None	Minimum 5s.	Report and Proceedings, annually
Hastings and St Leonards Natural History Society 1893	W de Muller, B A, 14 St Matthew's Gardens, St Leonards-on Sea	453	1s	3s 6d	'Hastings and East Sussex Naturalist,' occasionally
Hawick Archæological Society, 1856	J J Vernon, 81 High Street Hawick	300	None	2s 6d	Transactions, annually
Hull Society of Natural Science, 1904	A J Moore, 9 Brook Street, Hull	70	None	4s	Proceedings, occasionally
Inverness Scientific Society and Field Club, 1875	Thomas Wallace, Ellerslie, Inverness	180	None	5s	Transactions, occasionally
Ipswich and District Field Club, 1903	Miss Ellen E Joyce, 2 St John's Road, Ipswich	142	None	2s 6d	Journal, annually
Lancashire and Cheshire Entomological Society, 1877	Royal Institution, Liverpool H R Sweeting, M A	140	None	5s	Report and Proceedings, annually
Leeds Naturalists' Club and Scientific Association, 1868	Edward J T Ingle, 18 Strattan Street Leeds	100	None	5s	Proceedings, occasionally
Lewisham Antiquarian Society, 1885	J W Brookes, Pembroke Lodge, Slaithwaite Road, Lewisham, S E	91	None	5s	Transactions, occasionally
Liverpool Microscopical Society, 1868	Royal Institution, Liverpool R Croston	57	None	10s 6d	Report, annually
Liverpool Science Students' Association, 1881	Royal Institution, Liverpool H W Greenwood	48	2s 6d	5s	——
Llandudno and District Field Club, 1906	L S Underwood, Brinkburn, Llandudno	174	None	5s	Proceedings, annually
London City of London Entomological and Natural History Society 1858	The London Institution, Finsbury Circus, E C V E Shaw	76	2s 6d	7s 6d	Transactions, annually
London North London Natural History Society, 1892	T R Brooke, 12 Warren Road, Chingford	227	2s 6d	5s and 2s 6d	Report, annually
London South London Entomological and Natural History Society, 1872	Hibernia Chambers, London Bridge, S E Stanley Edwards, F L S and H J Turner, F E S	172	2s 6d	10s	Proceedings, annually
Maidstone and Mid-Kent Natural History Society, 1868	Maidstone Museum A Barton and J W Bridge	95	None	10s	Report, triennially
Newcastle-upon-Tyne, Literary and Philosophical Society of, 1793	Newcastle upon-Tyne Alfred Holmes and Frederick Emley	3,000	None	1l 1s	——
Penzance Natural History and Antiquarian Society, 1839	Public Buildings, Penzance J B Cornish	50	None	10s 6d	Transactions, occasionally
Preston Scientific Society 1893	Lecture Hall, 119A Fishergate, Preston F Chadderton	400	None	5s	Papers, occasionally
Scarborough Philosophical and Archæological Society, 1828	E Arnold Wallis, Springfield, Scarborough	120	None	1l, 10s, and 5s	Report, annually
School Nature Study Union, 1903	H E Turner, 1 Grosvenor Park, Camberwell, S E	1,600	None	2s 6d	'School Nature Study,' five times a year
Scottish Microscopical Society, 1885	Philosophical Institution, 4 Queen Street Edinburgh Dr W G Aitchison Robertson	65	None	10s 6d	Proceedings, occasionally
Southport Society of Natural Science, 1890	G H Hibbott, 156 Sussex Road, Southport	270	None	5s	Report, annually
Teign Naturalists' Field Club, 1858	John S Amery, Druid, Ashburton, Devon	120	None	2s 6d	Report, annually
Tunbridge Wells Natural History and Philosophical Society, 1884	Dr D Davies, 8 Lonsdale Gardens, Tunbridge Wells	140	None	10s 6d and 5s	Report, annually
Warrington Field Club, 1884	H Womersley, 20 White Street, Warrington	45	None	2s	——
Watford Camera Club, 1902	F H Haines, 100 High Street, Watford	60	None	10s and 5s	——

Catalogue of the more important Papers, especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending May 31, 1912

*** This Catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2

Section A —MATHEMATICAL AND PHYSICAL SCIENCE.

AITKEN, R G Life on Other Worlds 'Journal Royal Astr Soc of Canada,' v 291

ASHWORTH, Dr J R Remarks on an old Rainfall Record in Rochdale 'Trans Rochdale Lit Sci Soc' x 44–48 1911

BAIN, JAMES, and Dr J S HALDANE An Experiment on the Effects of reversing a Main Air current 'Trans Inst Min Eng' XLI 475–481 1911

BEATTIE, Dr J C Terrestrial Isomagnetic Lines for South Africa for the Epoch July 1, 1903 'Trans Royal Soc of S Africa,' II 283–286 1912

CAMPBELL-BAYARD, F Report of the Meteorological Committee, 1910 'Trans Croydon N H Sci Soc 1910-1911,' 13–38, and Appendices, 62 pp 1911

CANNON, J B The Orbit of *b* Persei 'Journal Royal Astr Soc of Canada,' v 266–271 1911

—— A Note on ϕ Persei. 'Journal Royal Astr. Soc of Canada,' v 372–376 1911

CARADOC AND SEVERN VALLEY FIELD CLUB Meteorological Notes 'Record of Bare Facts,' No 21, 22-36 1912

CHANT, C A A Great Modern Telescope 'Journal Royal Astr Soc of Canada,' v 309-314 1911

—— Mars The Planet of Mystery 'Journal Royal Astr Soc. of Canada,' v 408–417 1911

—— Strange Celestial Visitors—Comets and Meteors 'Journal Royal Astr Soc of Canada,' VI 88–98 1912

CLARKE, J E Presidential Address The Meteorology of the Upper Air 'Proc Croydon N H Sci Soc 1910–1911,' xxxiv–xliv 1911

COLLINS, S H A Combined Governor and Gauge for maintaining a regular flow of Gas, and a Thermostat with delicateadjustment and long range 'Proc Univ of Durham Phil Soc' IV 110–113 1912

COWIE, Dr JAMES M Burton-on-Trent Meteorological Summary, 1906–1910 Rainfall at Burton-on-Trent for Thirty-five Years, 1876–1910 'Trans Burton-on-Trent N H. A Soc' VI 95-100 1911

CRAW, J H. Account of Rainfall in Berwickshire—years 1909, 1910 'History Berwickshire Nat Club,' XXI 114, 216 1911

—— Account of Temperature at West Foulden—years 1909, 1910 'History Berwickshire Nat Club,' XXI 115, 217 1911

CRESSWELL, ALFRED Records of Meteorological Observations taken at the Observatory, Edgbaston, 1911 'Birm and Mid Inst Sci Soc' 27 pp 1912

DE LURY, RALPH E Errors in the Measurement of Spectral Line Displacements 'Journal Royal Astr Soc of Canada,' v 384–407. 1911

—— Presidential Address Theories of World Making 'Journal Royal Astr Soc of Canada,' VI. 1–14 1912

DEMPSTER, A J. Darwin's Tidal Theory 'Journal Royal Astr Soc of Canada,' v 185–199 1911

DYSON, F W. The Distances of the Stars 'Trans Ealing Sci Mic Soc. 1910–1911,' 14–16 1911

FOX, W LLOYD, and EDWARD KITTO Meteorological and Magnetical Tables and Reports for the year 1910, Tables of Sea Temperature, &c 'Report Royal Cornwall Poly Soc.' I (N S) 1–27 (App) 1911

GILL, Sir DAVID. Presidential Address. Wonders of the Heavens. 'South-Eastern Naturalist for 1911,' 1–7 1911.

GOLDSBOROUGH, G R A Survey of the Girdle Stanes 'Proc Univ. of Durham Phil Soc' IV 152–161. 1912

GRAY, Dr. JAMES G. On the Magnetic Properties of Nickel-Manganese Alloys 'Proc Glasgow Royal Phil Soc' XLII 125-129 1911

GURNEY, ROBERT The Tides of the River Bure and its Tributaries 'Trans Norfolk and Norwich Nat. Soc' IX 216-243 1911

HARPER, W. E The Orbit of σ Geminorum 'Journal Royal Astr Soc of Canada,' v 200-204 1911

—— The Orbits of the Spectroscopic Components of *d* Bootis 'Journal Royal Astr Soc of Canada,' v 315-326 1911

HAVELOCK, Dr T H The Displacement of the Particles in a case of Fluid Motion 'Proc Univ of Durham Phil Soc' IV 62-74 1911

HAWKE, E. L Meteorological Report for 1911 'Report Hampstead Sci Soc, 1911,' 29-31 1912

HEAWOOD, Prof PERCY J Modern Theories of Number considered as the Measure of Continuous Quantity 'Proc Univ of Durham Phil Soc' IV 113-128 1912

HOUGH, S S Presidential Address Photography an Aid to Astronomy 'Trans Royal Soc. of S Africa,' II 227-236 1912

INNES, A G Tidal Action in the Bure and its Tributaries 'Trans Norfolk and Norwich Nat Soc' IX 244-262 1911

INNES, R T A Relations between the Eccentricities and Inclinations of the Orbits of the Planets Jupiter and Saturn 'Trans Royal Soc of S Africa,' II 287-291 1912

—— The Algebraical Development of the Elliptic Perturbative Function used in the Theories of Planetary Motion 'Trans Royal Soc of S Africa,' II 301-317 1912

JENKIN, ARTHUR P Summary of Meteorological Observations at Trewirgie, Redruth, 1911 'Journal Royal Inst of Cornwall,' XIX 147-148 1912

JONES, Dr W. MAKEIG The Tides and Tidal Currents 'Journal Torquay N H Soc' I 163-169 1912

KLOTZ, OTTO Terrestrial Magnetism 'Journal Royal Astr Soc of Canada,' v. 157-171. 1911

—— Stereographic Projection Tables 'Journal Royal Astr Soc of Canada,' v 205-215 1911

—— Location of Epicentres for 1911 'Journal Royal Astr Soc of Canada,' VI 15-23 1912

LAWSON, GRAHAM C Meteorological Report 'Trans N Staffs F C' XLVI 124-132 1912

LONG, Dr SYDNEY H 'Blowing' Wells 'Trans Norfolk and Norwich Nat Soc' IX. 191-192 1911

MCALDOWIE, Dr ALEXANDER M Prehistoric Time Measurement in Britain An Astronomical Study of some Ancient Monuments 'Trans N Staffs F C' XLVI 155-170 1912

MARCHANT, Prof E W Illumination 'Trans Liverpool Eng Soc' XXXII 124-136 1911

MARKHAM, C A, and R H PRIMAVESI Meteorological Report 'Journal Northants N H Soc' XVI 66-70, 103-106, 141-146, 178-181 1911, 1912

MEYRICK, E Summary and Tables of Meteorological Observations 'Report Marlb Coll N H Soc' No 59, 55-76 1911

MILL, Dr H. R. Twenty-nine Years' Rainfall at Wetwang 'The Naturalist for 1911,' 251-253 1911

MOIR, Dr JAMES The Spectrum of the Ruby—Part II—and the Artificial Ruby 'Trans Royal Soc of S Africa,' II 271-272 1912

—— Notes on the Spectra of the Precious Emerald and other Gem-stones 'Trans Royal Soc of S Africa,' II 273 1912

MUIR, Dr THOMAS Sylvester's and other Unisignants 'Trans Royal Soc of S. Africa,' II. 187-195 1912

—— Sylvester's Axisymmetric Unisignant 'Trans Royal Soc of S Africa,' II 197-202 1912

NELSON, EDWARD M On Methods of Illumination 'Journal Quekett Mic Club,' XI. 289-298. 1911

—— An Improved Compound Microscope by James Mann 'Journal Quekett Mic Club,' XI. 317-320 1911

NEVILL, E. On the Early Babylonian Eclipse of the Sun 'Trans Royal Soc of S Africa,' II. 243-260. 1912.

NUGENT, D B. Personal Errors of Bisection in Meridian Circle Work 'Journal Royal Astr Soc of Canada,' v 272–276 1911

PAINTER HUBERT The Graphic Solution of Problems relating to the Laws of Boyle and Charles 'Proc Bournemouth Nat Sci Soc' III 102–104 1912

PARKER, T H The Orbit of ω Ursae Majoris 'Journal Royal Astr Soc of Canada,' v 377–383 1911

PATERSON, J H A Modified Form of the Landsberger Boiling Point Apparatus 'Proc Univ of Durham Phil Soc' IV 142–144 1912

PENROSE, GEORGE Summary of Meteorological Observations at Truro for the year 1911 'Journal Royal Inst of Cornwall,' XIX 143–146 1912

PLASKETT, J S Some recent interesting Developments in Astronomy 'Journal Royal Astr Soc of Canada,' v 245–265 1911

—— The Spectrum of Nova Geminorum 'Journal Royal Astr Soc of Canada,' VI. 27–36 1912

POPE, JOSEPH Astronomy as a Recreation 'Journal Royal Astr Soc of Canada,' VI 99–116 1912

PRESTON, ARTHUR W Meteorological Notes, 1910 'Trans Norfolk and Norwich Nat Soc' IX 205–212 1911

PRIESTLEY, C W Cyclones 'Journal Torquay N H Soc' I 170–172 1912

RAMBAUT, A A Summary of the Weather during 1911, from Observations made at the Radcliffe Observatory, Oxford 'Report Ashmolean Nat Hist Soc 1911,' 41 1912

—— Characteristics of the Weather at Oxford in 1911 'Report Ashmolean Nat Hist Soc 1911,' 36–40 1912

ROSS, ALEXANDER D The Origin of Magnetic Storms 'Proc Glasgow Royal Phil Soc' XLII 131–136 1911

ROYAL ASTRONOMICAL SOCIETY OF CANADA Notes from the Meteorological Service 'Journal Royal Astr Soc of Canada,' v 225–231, 277–281, 341–345, 439–444, 1911, VI 56–62 133–138, 1912

RUTHERFORD, Prof E Transformations of Radio active Matter 'Trans Rochdale Lit Sci Soc' X 92–96 1911

RUTHERFORD, J Weather and Natural History Notes, 1910 'Trans Dumfriesshire and Galloway N H A Soc' XXIII 263–269 1911

SIMPSON, the late T Meteorological Notes for the years 1909 and 1910 'Report Ealing Sci Mic Soc 1910–1911,' XI 1911

SMITH, H On the best Use of a Condenser when used as a Shunt to a Telephone in Wireless Telegraphy 'Proc Univ of Durham Phil Soc' IV 167–172 1912

STARLING, COLMAN C The Practice of Photographing in Colours 'South-Eastern Naturalist for 1911,' 8–9 1911

STILWELL, H Returns of Rainfall, &c, in Dorset in 1910 'Proc Dorset N H A F C' XXXII 185–198 1911

STUPART, R F Meteorology in Canada 'Journal Royal Astr Soc of Canada,' VI 75 87 1912

SUTTON, Dr J R A Note on the Land and Sea Breezes of South Africa 'Trans Royal Soc of S Africa,' II 293–300 1912

THOMPSON, BEEBY Water Divining and Radioactivity 'Journal Northants N H Soc' XVI 92–100 1911

TINNE, P F Presidential Address A Short History of the Microscope and what it has done for us 'Forty-third Report Liverpool Mic Soc' 8–24 1912

TURNER, A B The Moon's Orbit around the Sun 'Journal Royal Astr Soc of Canada,' VI 117–119 1912

WALFORD, Dr E Meteorological Observations in the Society's District, 1909 'Trans Cardiff Nat Soc' XLIII 1–14 1911

WATSON, A D Calendars, Ancient and Modern 'Journal Royal Astr Soc of Canada,' v 172–184 1911

WATT, ANDREW Rainfall Records of the Southern Counties for the year 1910 'Trans Dumfriesshire and Galloway N H A Soc' XXIII 270–271 1911

YOUNG, REYNOLD Spectroscopic and Visual Binaries An Outline of Work done in this Field and an Indication of its Importance 'Journal Royal Astr Soc of Canada,' v 355–371. 1911

Section B —CHEMISTRY.

BENGOUGH, G D The Corrosion of Brass and Copper 'Trans Liverpool Eng Soc' XXXII 171–190 1911

BONNER, ALLEN H (Mid Counties Inst Eng) The Causes of Boiler Deterioration and their Remedy 'Trans Inst Min Eng' XLIII 202–211 1912

COLLINS, S H The Rate of Evolution of Hydrocyanic Acid from Linseed under Digestive Conditions 'Proc Univ of Durham Phil Soc' IV 99–106 1912

—— A Water-sealed Constant-pressure Hydrogen Gas Generator 'Proc Univ of Durham Phil Soc' IV 107–109 1912

GARFORTH, W E (Manchester Geol Min Soc) Presidential Address British Coal-dust Experiments 'Trans Inst Min Eng' XLII 220–241 1912

HALDANE, Dr J S A Flame-test for the Estimation of Oxygen and Black damp in Naked-light Mines 'Trans Inst Min Eng' XLI 455–462 1911

HALL, Dr A A The Relation between the Chemical Composition and the Position of some North Country Clays 'Proc Univ of Durham Phil Soc' IV 83–89 1911

HARGER, Dr JOHN (Manchester Geol Min Soc) The Prevention of Explosions in Mines 'Trans Inst Min Eng' XLIII 132–152 1912

KEEGAN, Dr P Q The Chemistry of some Common Plants 'The Naturalist for 1911,' 222–224, 418–419 1911

KERSHAW, J B C The Control of Fuel Supplies 'Trans Liverpool Eng Soc' XXXII 36–53 1911

MOIR, Dr JAMES Colloidal Gold and 'Purple of Cassius' 'Trans Royal Soc of S Africa,' II 203–204 1912

—— Some remarkable Oxidation products of Benzidine 'Trans Royal Soc of S Africa,' II 205–210 1912

PATERSON, J H The Analysis of Vinegar 'Proc Univ of Durham Phil Soc' IV 144–146 1912

PATTERSON, Dr T S The Study of Intra Molecular Change 'Proc Glasgow Roy Phil Soc' XLII 10–25 1911

—— and ANDREW MCMILLAN The Rate of Transformation of *Syn* into *Anti* Oximes 'Proc Glasgow Roy Phil Soc' XLII 26–33 1911

RUDGE, W A DOUGLAS Preliminary Note on the Meteorites in the Bloemfontein Museum 'Trans Royal Society of S Africa,' II 211–221 1912

SMYTHE, J A Benzylorthothioformate 'Proc Univ of Durham Phil Soc' IV 75–83 1911

STENHOUSE, T New Methods of forming Metallic Films by Chemical Means 'Trans Rochdale Lit Sci Soc' X 26–29 1911

THOMPSON, BEEBY Peculiarities of Waters and Wells 'Journal Northants N H Soc' XVI 121–133, 147–157 1912

TRAVIS, C B, and H W GREENWOOD The Mineralogical and Chemical Constitution of the Triassic Rocks of Wirral 'Proc Liverpool Geol Soc' XI 116–139 1911

Section C —GEOLOGY

BALDWIN, WALTER The Pleistocene Lakes of Rochdale 'Trans Rochdale Lit Sci Soc' X 17–21 1911

BARKE, F Geological Report 'Trans N Staffs F C' XLVI 121–123 1912

BATES, GEORGE F Notes on some Highland Rocks 'Trans Perthshire Soc Nat Sci' V 94–102 1911

BEASLEY, H C Description of a Group of Footprints in the Storeton Find of 1910 'Proc Liverpool Geol Soc' XI 108–115 1911

BENNEY, A E The Yellow Clay 'Bradford Scientific Journal, III 182–186 1911

BOULTON, Prof W S The Underground Water Supply of Cardiff 'Trans Cardiff Nat Soc' XLIII 32–35 1911

—— An Occurrence of Jet at Lower Penarth 'Trans Cardiff Nat Soc' XLIII 36–38 1911

BUCKMAN, S S A Method of removing Tests from Fossils 'The Naturalist for 1912,' 139–140 1912

CLARK, E GRAHAM The Geology of South-Western France 'Proc Univ of Durham Phil Soc' IV 134–141 1912

COCKIN, GEORGE M Notes on the Cannock Chase Coalfield. 'Trans Burton-on-Trent N H A Soc' VI 29–35 1911

—— (N Staff Inst Eng) The Carboniferous Limestone of Fair Oak, Cannock Chase Coalfield 'Trans Inst Min Eng' XLI 323–327. 1911

COLE, Prof GRENVILLE A J The Close of an Ice-age A Comparison between Ireland and Spitsbergen in 1910 'Proc Belfast Nat F C' VI 441–443 1911

COLLINS, J H Description of a Fossil (cf Actinoceras Devonicans) from Rope Haven, St Austell Bay 'Journal Royal Inst of Cornwall,' XIX 36–39 1912

DURHAM, UNIVERSITY OF, PHILOSOPHICAL SOCIETY Report No 5 of the Boulders Committee, May 1911 'Proc Univ of Durham Phil Soc' IV 89–91 1911

GRAY, JOSEPH W The North and Mid Cotteswolds and the Vale of Morton during the Glacial Epoch 'Proc Cotteswold Nat Field Club,' XVII 257–274 1911

GRAY, WILLIAM A Talk on Limestone 'Proc Belfast Nat F C' VI 445–447 1911

GUY, ERNEST On the Formation of Cavities in the Magnesian Limestone. 'Trans Leeds Geol Assoc' XVI 10–15 1911

HARKER, ALFRED Petrology in Yorkshire 'The Naturalist for 1912,' 37–44, 69–73 1912

—— Appendix on the Igneous Rocks 'The Naturalist for 1912,' 111–113 1912

HASELHURST, S RENNIE A Case of Megascopic Pseudostromatism in the D_5 Coal Measures of Northumberland 'Proc Univ of Durham Phil Soc' IV 162–166 1912

HAWKESWORTH, E Notes on Permian Boulders found at Rothwell Haigh 'Trans. Leeds Geol Assoc' XVI 31 1911

HESLOP, MARY K A Preliminary Note on the Uniaxial Augites of the North of England Igneous Dykes 'Proc Univ. of Durham Phil Soc' IV. 172–174 1912

HEWITT, W List of Papers, &c, on the Geology of the Country round Liverpool, from 1890 to 1909 'Proc Liverpool Geol Soc' XI 59–75 1911

—— Presidential Address The Physical Conditions under which the Local Triassic Rocks were formed 'Proc Liverpool Geol Soc' XI 79–107 1911

HINCH, J DE W A High Level Deposit of Marine Shells in Curraun Achill, Co Mayo 'Irish Naturalist,' XX 189–193 1911

IRVING, Rev A Note on the Bishop's Stortford Sub-fossil Horse Skeleton. 'Essex Naturalist,' XVI 282–285 1911

JACKSON, J WILFRID A New Species of Unio from the Yorkshire Estuarine Series, with Notes on other Forms 'The Naturalist for 1911,' 211–215 1911

JOHNSON, J W H Composition of the Upper Permian Limestone in South Lincolnshire 'The Naturalist for 1911,' 308 1911

KENDALL, Prof P F Notes on the Geology of the Vale of Eden 'The Naturalist for 1912,' 105–111 1912

—— Presidential Address [The Progress made by Geology in Yorkshire during the past half century] 'Proc Yorkshire Geol Soc' XVII 169–183 1912

KING, W NORMAN The Cleveland Dyke 'Trans. Leeds Geol Assoc' XVI 16–23 1911

LAMPLUGH, G W On the Shelly Moraine of the Lefstrom Glacier and other Spitzbergen Phenomena illustrative of British Glacial Conditions 'Proc Yorkshire Geol Soc' XVII 216–241 1912

LOMAX, JAMES (Manchester Geol Min Soc) The Microscopical Examination of Coal and its use in determining the Inflammable Constituents present therein. 'Trans Inst Min Eng' XLII 2–15 1911.

MCMURTIE, JAMES On a Boring at Puriton, near Bridgewater, in search of Coal South of the Mendip Hills 'Proc Somersetshire Arch N. H Soc' LVII 25–53 1912

MAIDWELL, F T Notes on Footprints from the Keuper of Runcorn Hill. 'Trans Liverpool Geol Soc' XI 140–152 1911.

MORRIS, Sir DANIEL Nipadites in Eocene Beds at Bournemouth 'Proc. Bournemouth Nat Sci Soc' III 78–81 1912

MOYSEY, L On the Discovery of *Anthrapalaemon* in the Nottinghamshire Coalfield. 'Report Nottingham Nat Soc 1910–11,' 45–46 1912

PARIS, E TALBOT. Notes on some Species of Gervillia from the Lower and Middle Jurassic Rocks of Gloucestershire. 'Proc Cotteswold Nat. Field Club,' XVII. 237–254. 1911.

PARIS, E. TALBOT Note on *Gervillia acuta* auctt non Sowerby (*G scarburgensis* nov nom.) from the Scarborough Limestone 'Proc Cotteswold Nat Field Club,' XVII 255–256 1911

PARKER, W A A Description of Sandstones representing Twenty-five Quarries in the neighbourhood of Rochdale 'Trans Rochdale Lit Sci Soc' X 80–88 1911

—— Fossil Arachnid found at Sparth 'Trans Rochdale Lit Sci Soc' X 89–91 1911

PICKERING, G F Notes on the Lithology of the Millstone Grit (Rough Rock) of Horsforth, near Leeds 'Trans Leeds Geol Assoc' XVI 27–30 1911

RAVN, J P J Notes on the Cretaceous Fossils in the East Yorkshire Drift 'The Naturalist for 1912,' 8 1912

RICHARDSON, LINSDALL The Inferior Oolite and Contiguous Deposits of the Chipping Norton District, Oxfordshire 'Proc Cotteswold Nat Field Club,' XVII 195–235 1911

—— The Lower Oolitic Rocks of Yorkshire With Appendices by S S Buckman and E T Paris 'Proc Yorkshire Geol Soc' XVII 184–215 1911

ST BARBE, H Notes on River Courses in the South of England 'Proc Bournemouth Nat Sci Soc' III 84–95 1912

SHEPPARD, T Extinct Animals of East Yorkshire 'The Naturalist for 1911,' 225–230 1911

—— Bibliography Papers and Records published with respect to the Geology and Palæontology of the North of England (Yorkshire excepted) during 1909 'The Naturalist for 1911,' 257–270 1911

—— —— during 1910 'The Naturalist for 1912,' 152–160 1912

—— Coast Changes at Hornsea 'The Naturalist for 1912' 114–120 1912

SMITH, STANLEY The Faunal Succession of the Upper Bernician 'Trans Northumberland N H Soc' III 591–645 1911

STATHER, J W Shelly Clay from the Dogger Bank 'The Naturalist for 1912,' 138 1912

—— Notes on the Belemnites of the Yorkshire Chalk 'Proc Yorkshire Geol Soc' XVII 246–250 1912

STRACHAN, J The Onyx of Spanish Bay, Giant's Causeway its Occurrence and Origin 'Proc Belfast Nat F C' VI 401–404 1911

VAUGHAN, ARTHUR Notes on *Clisiophyllum ingletonense*, sp nov 'Proc Yorkshire Geol Soc' XVII 251–255 1912

WALLACE, ROBERT The Formation and Age of the Queensberrys, illustrated by Graptolites 'Trans Dumfriesshire and Galloway N H A Soc' XXIII 245–254 1911

WICKES, W H Beekite 'Proc Bristol Nat Soc' II Part III 9–21 1911

WILMORE, Dr ALBERT Note on the Zones of the Carboniferous Limestone South of the Craven Fault 'Proc Yorkshire Geol Soc' XVII 242–245 1912

WINWOOD, Rev H H The Geology of Vallis 'Proc Somersetshire Arch N H. Soc' LVII 28–32 1912

WITHERS, THOMAS H On the Occurrence of *Pollicipes* in the Inferior Oolite 'Proc Cotteswold Nat Field Club,' XVII 275 1911

WRIGHT, JOSEPH Boulder-Clays from the North of Ireland, with Lists of Foraminifera 'Proc Belfast Nat F C' VI (App No I of Vol III), 1–8 1911

—— Foraminifera from the Estuarine Clays of Magheramorne and Limavady 'Proc Belfast Nat. F C.' VI (App. No. II. of Vol III), 9–19 1911

YEILAND, W The Working of a Lead Mine, with some Remarks concerning the Formation of Mineral Veins 'Trans Caradoc and Severn Valley F. C' v. 203–212 1912

Section D—ZOOLOGY

BAGNALL, RICHARD S A Contribution towards a Knowledge of the British Species of the Order Symphyla 'Trans Northumberland N H Soc' III 646–653 1911

—— A Synopsis of the British Pauropoda 'Trans Northumberland N H Soc' III. 654–660. 1911

—— On Two New Species of *Trichothrips* from the Derwent Valley 'Trans Northumberland N. H. Soc.' III 661–663 1911

BARNES, F. J. Lobsters. 'Proc Dorset N H A. F C' XXXII 73–94 1911.

BARRINGTON, R M. The Great Rush of Birds on the Night of March 29th–30th [1911], as observed in Ireland. 'Irish Naturalist,' XX 97–110. 1911.

BARRINGTON, R. M. Further Notes on the Fulmar 'Irish Naturalist' xx 152–154 1911

BAYFORD, E G *Carpophilus sexpustulatus* F, its Congeners, and their Occurrence in the British Isles 'The Naturalist for 1912,' 141–145 1912

BESSELL, J B Moorland Diatoms 'Journal Torquay N H Soc' I 179–182 1912

—— Fauna and Flora of the Torquay District No 1, Diatomaceæ 'Journal Torquay N H Soc' I 182–186 1912

BLADEN, W WELLS Bird Notes (1911), chiefly taken at Stone 'Trans N Staffs F C' XLVI 94–102 1912

BLOOMFIELD, Rev E N Annual Notes on the Local Fauna, Flora, &c 'Hastings and East Sussex Naturalist,' I 304–310 1911

BONAPARTE WYSE, L H Entomological Notes from Co Galway 'Irish Naturalist,' XXI 37–39 1912

BOOTH, FRED Shipley Glen and its Molluscan Fauna 'Bradford Scientific Journal,' III 161–166 1911

BOOTH, H B Notes on the Nesting of the Blue Titmouse, the Starling, and the Robin 'Bradford Scientific Journal,' III 166–172 1911

BOSTOCK, E D Entomological Report 'Trans N Staffs F C' XLVI 103–111 1912

BROWNE, F BALFOUR The Aquatic Coleoptera of the South-east of Ireland 'Irish Naturalist,' XXI 1–16. 1912

BRYCE, DAVID On Three New Species of Callidina 'Journal Quekett Mic Club,' XI 363–370 1912

BURTON, R F L The Culcidae of Shropshire 'Trans Caradoc and Severn Valley F C' V 200–202 1912

BUTTERFIELD, E P Micro-Lepidoptera of the Bradford District 'Bradford Scientific Journal,' III 186–191 1911

BUTTERFIELD, J A A Note on the Common Lizard 'Bradford Scientific Journal,' III 141–142 1911

CARADOC AND SEVERN VALLEY FIELD CLUB Zoological Notes 'Record of Bare Facts,' No 21, 13–21 1912

CARTER, C S Lincolnshire Chalk Foraminifera 'The Naturalist for 1911,' 302 1911

CLARKE, W J A New Yorkshire Reptile 'The Naturalist for 1911,' 305 1911

COTTON, J D The Birds of Northamptonshire and Neighbourhood 'Journal Northants N H Soc' XVI 158–161 1912

CROWFOOT, W M Presidential Address Lessons to be learnt from a Large Collection of Butterflies 'Trans Norfolk and Norwich Nat Soc' IX 143–169. 1911

CURTIS, W PARKINSON Remarks on *Psilopleura haemasoma*, D Jones 'Proc. Bournemouth Nat Sci Soc' III 95–98 1912

DAKIN, Dr W J Plankton Studies 'Proc Belfast Nat F C' VI 449–451 1911

DELAP, ALFRED D (with note by R M BARRINGTON) The Autumn Migration of Swallows at Rosslare Harbour 'Irish Naturalist,' XXI 65–72 1912

DOBBS, MISS M E (with notes by C B MOFFAT) Luminous Owls 'Irish Naturalist,' XX 121–131 1911

ELMHIRST, RICHARD Some Echinorhynchs from the Clyde Area 'Glasgow Naturalist,' IV 88–90 1912

FALCONER, WM New and Rare Yorkshire Spiders 'The Naturalist for 1911,' 283–288 1911

—— Yorkshire Arachnida in 1911 'The Naturalist for 1912,' 52–54 1912

FERGUSSON, ANDERSON Additions to the List of Clyde Coleoptera Second Paper 'Glasgow Naturalist,' IV 70–81 1912

FLETCHER, J H The Gull 'Journal Northants N H Soc' XVI 118–120 1912

FORREST, H E Everyday Mistakes in Natural History 'Trans Caradoc and Severn Valley F C' V 245–250. 1912

FORTUNE, R The Vertebrate Fauna of Harewood 'The Naturalist for 1911,' 247 1911

—— Cock Partridges 'Mothering' Chicks hatched in an Incubator 'The Naturalist for 1911,' 277. 1911

—— Game Birds and their Broods killed by Lightning near Harrogate. 'The Naturalist for 1911,' 280 1911.

FOSTER, NEVIN H On Two Exotic Species of Woodlice found in Ireland 'Irish Naturalist,' xx 154–156 1911

FRIEND, Rev HILDERIC Enchytraeids of the North of England 'The Naturalist for 1911,' 289–293, 318–321 1911

—— Annelid Bionomics 'The Naturalist for 1911,' 394–398 1911

—— New Records for British Annelids 'The Naturalist for 1911,' 411–417 1911

—— Oligochaets of Great Britain and Ireland 'The Naturalist for 1912,' 76–81. 1912

—— Annelid Hunting in Notts 'Report Nottingham Nat Soc 1910–11,' 30–44 1912

GEORGE, C F *Trombidium buccinator* 'The Naturalist for 1911,' 380–381 1911

—— *Bdella hexopthalma* Gervais 'The Naturalist for 1912,' 47–48 1912

—— Some British Earthmites 'The Naturalist for 1912,' 74–75 1912

GURNEY, J H The Great Auk (*Alca impennis*) and its Egg, in Norwich Museum. 'Trans Norfolk and Norwich Nat Soc' IX 214–215 1911

HANSON, CHARLES, jun Dates of Arrivals of Summer Migrants, as noticed in Burton-on-Trent District, 1906–1909 'Trans Burton-on-Trent N H A Soc' VI 94 1911

HOLLIS, W H Fresh-water Sponges 'Journal Northants N H Soc' XVI 91 1911

HORRELL, E CHARLES The Beetles of the Scarborough District 'The Naturalist for 1912,' 49–50 1912

—— A New British Beetle (*Chaetocnema conducta*) 'The Naturalist for 1912,' 82–83 1912

HULL, Rev J E On Spiders I The Genus *Tmeticus* (Simon, 1884, Cambridge, 1900) and some Allied Genera, II Some Northern Records for 1909 'Trans Northumberland N H Soc' III 573–590 1911

HURRELL, H E Distribution of the Polyzoa in Norfolk Waters 'Trans Norfolk and Norwich Nat Soc,' IX 197–205 1911

HUTTON, W HARRISON The Boring Habits, &c, of the Pholas 'The Naturalist for 1911,' 423–424 1911

IRVING, Dr JOHN Anemones on the Yorkshire Coast 'The Naturalist for 1911,' 246 1911

—— Marine Biology at Scarborough 'The Naturalist for 1911,' 327–328 1911

—— Variations in Teeth of Whelk 'The Naturalist for 1911,' 357–358 1911

—— The Boring Habits of the Pholas 'The Naturalist for 1912,' 45–46 1912

JOHNSON, Rev W F Ichneumonidae and Braconidae from the North-east of Ireland. 'Irish Naturalist,' XXI 77–79 1912

JONES, Staff-Surgeon K J Notes of certain Terrestrial and Fluviatile Mollusca from Glengarriff, Co Cork 'Irish Nationalist' XX 137–139 1911

KAYE, W J Annual Address [Entomology in 1911] 'Proc South London Ent and N H Soc 1911–12,' 6–22 1912

KENNARD, A S, and B B WOODWARD Notes on Non Marine Mollusca from some Irish Lakes, obtained by the late Major H Trevelyan, F Z S, in 1911 'Irish Naturalist,' XXI 93–99 1912

KERR, J GRAHAM Loch Sween 'Glasgow Naturalist,' IV 33–48 1912

LINDNER, Pastor C 'Ignis Fatuus' versus 'Luminous Owls' 'Irish Naturalist,' XX 177–178 1911

—— Luminous Owls Supplementary Note 'Irish Naturalist,' XXI 52–53 1912

LUMBY, A HAIGH The Birds of Walney Island 'The Naturalist for 1911,' 281–282 1911

MASFIELD, J R B. Zoological Report 'Trans N Staffs F C' XLVI 81–93 1912

MASON, G W The Lepidoptera of Lincolnshire Part IV 'Trans Lincolnshire Nat Union, 1910,' 176–219 1911

MATTHEWS, C G Natural History Observations from Burton Bridge 'Trans Burton-on-Trent N H A Soc' VI 67–69 1911

—— Natural History Notes 'Trans Burton-on-Trent N H A Soc' VI 70–72 1911

'MEDHIC' Amputation in the Insect World 'Bradford Scientific Journal,' III 136–137 1911

MEEK, Prof. ALEXANDER Early Stages in the Development of the Vertebrates 'Proc. Univ. of Durham Phil. Soc.' IV. 129–133. 1912.

MEYRICK, E Report of the Entomological Section 'Report Marlb Coll N. H. Soc.' No. 59, 34–41. 1911.
—— Ornithological List 'Report Marlb Coll N H Soc' No 59, 42–47 1911
MINCHIN, Prof E A Presidential Address Speculations with regard to the Simplest Forms of Life and their Origin on the Earth 'Journal Quekett Mic Club,' xi 339–364. 1912
NICHOLSON, Dr G W A Second List of Coleoptera from the County Meath 'Irish Naturalist,' xx 139–140 1911
NOWERS, J. E. The 'Breaking' of Barton Fishpond 'Trans Burton-on-Trent N H. A Soc' vi 73–78 1911.
O'DONOHOE, T A Dimorphism in the Spermatozoa of the Flea and Blow fly 'Journal Quekett Mic Club,' xi 313–316 1911
PACK-BERESFORD, D R Some New Irish Spiders 'Irish Naturalist,' xx 173–177. 1911.
PARKIN, THOMAS Beauport, near Battle, and its Rookery 'Hastings and East Sussex Naturalist,' i 293–296. 1911.
—— The Great Auk. A Record of Sales of Birds and Eggs by Public Auction in Great Britain, 1806–1910 'Hastings and East Sussex Naturalist,' i (Extra Paper, 36 pp). 1911
PARSONS, E A, and T. STAINFORTH Additions to the List of East Yorkshire Spiders 'Trans Hull Sci F. N Club,' iv 162–165 1911
PATERSON, JOHN The Return of Summer-Birds to the 'Clyde' Area in 1912 'Glasgow Naturalist,' iv 66–70 1912.
PATTEN, Dr C. J. Remarkable Nidification of a Kestrel 'The Naturalist for 1911,' 306–307. 1911.
—— Some Birds New to Ireland 'Irish Naturalist,' xxi 49–51 1912
PATTERSON, ARTHUR H. Natural History Notes from Yarmouth 'Trans Norfolk and Norwich Nat Soc' ix 193–197 1911
PENARD, Dr. E. On some Rhizopods from Sierra Leone 'Journal Quekett Mic Club,' xi 299–306. 1911
PHILIP, R H Additions to the List of the Diatomaceæ of the Hull District 'Trans Hull Sci F N Club,' iv 166–168 1911
PICKARD-CAMBRIDGE, Rev. O On New and Rare Arachnids noted and observed in 1910. 'Proc Dorset N H A F C.' xxxii 33–54 1911
—— On the Arachnida of Oxfordshire 'Report Ashmolean Nat Hist Soc. 1911,' 55–66. 1912.
PROGER, T. W., and D R PATERSON. Ornithological Notes 'Trans Cardiff Nat Soc.' xliii. 39–43 1911
REGAN, C. TATE British Fishes of the Salmon Family 'Trans Ealing Sci Mic Soc. 1910–1911,' 25–28 1911
RICHARDSON, NELSON M Anniversary Address. 'Proc Dorset N H. A F. C' xxxii. 1–22 1911.
ROBERTSON, JOHN Waders observed at Balgray Dam, East Renfrew (Autumn, 1911) 'Glasgow Naturalist,' iv. 7–10 1911.
ROEBUCK, W. DENISON Presidential Address 'Trans Lincolnshire Nat Union, 1910,' 161–175 1911.
ROLLASON, W A The Macro-lepidoptera of Falmouth and District to 1910 'Report Royal Cornwall Poly. Soc.' i (N S), 540–552. 1911
ROUSSELET, CHARLES F. On *Notholca triarthroides* Skorikow, *Cathypna brachydactyla* Stenroos, and on a new Brachionus from Devil's Lake, North Dakota 'Journal Quekett Mic. Club,' xi. 371–374. 1912
ST. QUINTIN, W. H The Bearded Tit in Holderness. 'The Naturalist for 1911,' 279–280 1911.
SAVILLE-KENT, the late W. Contributions to a Knowledge of the Hydrachnidae 'Journal Quekett Mic. Club,' xi. 261–288. 1911.
SCHARFF, Dr. R F. The Irish Whale Fishery 'Irish Naturalist,' xx. 141. 1911
SCHLESCH, HANS. *Petricola pholadiformis* Lam. 'The Naturalist for 1911,' 278 1911.
SCOTT, Dr THOMAS. Some Trematodes Parasitic on British Fishes. 'Trans Edinburgh F. N Mic. Soc.' vi 344 353. 1911
SCOURFIELD, D J. The Use of the Centrifuge in Pond-life Work 'Journal Quekett Mic. Club,' xi. 243–250. 1911.
SERVICE, ROBERT. Bird Migration in Solway. 'Trans Edinburgh F. N. Mic Soc.' vi. 295–309. 1911.

SIDDALL, C. K. Bird Life in a Suburban Garden. 'Proc. Chester Soc Nat. Sci. 1910–1911,' 3–14 1911

SIDEBOTTOM, HENRY Lagenae of the South West Pacific Ocean 'Journal Quekett Mic Club,' XI 375–434 1912

SMITH, ARTHUR Lincolnshire Crustacea 'Trans Lincolnshire Nat Union, 1911,' 300–302 1912

SMITH, D MUNRO Notes on a few Birds of the District 'Proc Bristol Nat. Soc.' III Part I 26–27 1911

SMITH, SYDNEY H Water Voles making Nests above Ground 'The Naturalist for 1912,' 7 1912

SOAR, CHARLES D The Work of the late Saville-Kent on British Hydrachnids 'Journal Quekett Mic Club,' XI 251–260 1911

STAINFORTH, T Notes on some Scarborough Coleoptera and Arachnida 'Trans. Hull Sci F. N. Club,' IV 144–146 1911

STEPHENS, NORMAN E Some Terrestrial Isopoda found in Cos Dublin and Wicklow during 1911 'Irish Naturalist,' XX 195–196 1911

SWANTON, E W The Mollusca of Somerset 'Proc Somersetshire Arch N H Soc' LVII 15–54 1912

—— Notes on Somerset Fungi 'Proc Somersetshire Arch N H Soc' LVII 66–73 1912

THOMAS, H The Structure of a Jelly Fish 'Proc Llandudno and District F C 1909–10,' 115–120 1912

THOMASSON, M W The Evolution and Dispersion of Freshwater Mollusca 'Trans Caradoc and Severn Valley F C' V 233–244 1912

THORNLEY, Rev A, and W. WALLACE Lincolnshire Coleoptera: Parts IV and V 'Trans Lincolnshire Nat Union, 1910,' 220–227, 1911, 245–289, 1912

UPTON, CHARLES A Revised List of the Land and Fresh-water Mollusca of Gloucestershire 'Proc Cotteswold Nat Field Club,' XVII 177–193 1911

USSHER, R J The Fulmar Petrel Breeding in Ireland 'Irish Naturalist,' XX 149–152 1911

WALKER, JAMES J Third Supplement to the Preliminary List of Coleoptera in the Report for 1906 'Report Ashmolean Nat Hist Soc 1911,' 45–54 1912

WALLACE, W Presidential Address The Progress made in the Study of the Local Coleoptera 'Trans Lincolnshire Nat Union, 1911,' 237–244 1912

WATSON, ARNOLD T Marine Biology at Scarborough 'The Naturalist for 1912,' 9 1912

WELCH, R J Presidential Address Facts about the Distribution of some Animals and Plants 'Proc Belfast Nat F C' VI 393–396 1911

WHITAKER, A, and E G BAYFORD Yorkshire Entomology in 1911 'The Naturalist for 1912,' 55–56 1912

WHITEHEAD, HENRY Report on Marine Specimens dredged from the Estuaries of the Orwell and Stour on the occasion of the Club's Expedition, 23 July, 1910 'Essex Naturalist,' XVI 193–198 1911

—— Dutrochet's Land Leech (*Trocheta subviridis*) in Essex 'Essex Naturalist,' XVI 219–221 1911

WILSON, R W S and H W A Visit to Castle Loch, Mochrum 'Glasgow Naturalist,' IV 1–4 1911

WILSON, W Notes on the Fæces of Young Birds 'The Naturalist for 1912,' 50–51 1912

WOODS, Rev F H Marine Biological Meeting at Scarborough 'The Naturalist for 1911,' 420–422 1911.

Section E—GEOGRAPHY.

FLINN, W. LEONARD. A Journey in Northern Persia 'Journal Manchester Geog. Soc' XXVII 21–28 1912

HOPKINSON, JOHN. The Hertfordshire Bourne 'South-Eastern Naturalist for 1911,' 10–19 1911.

Section F—ECONOMIC SCIENCE AND STATISTICS

MEACHEM, ISAAC (S. Staff. and Warw. Inst. Eng). Notes on the Loss of Mineral Areas in South Staffordshire. 'Trans. Inst. Min Eng.' XLIII. 11–17. 1912.

NIVEN, Dr. JAMES. The Cost of Disease. 'Trans. Manchester Stat Soc' IX. 139–169 1911.

O'CONNELL, Dr J R The Juvenile Street Trader and the State The Problem of the Waifs and Strays 'Journal Stat Soc Ireland,' XII 489–507 1911.

O'DONAHUE, T A (S Staff and Warw Inst Eng) Notes on the Valuation of Mineral Properties 'Trans Inst Min Eng' XLIII 19–38 1912

OLDHAM, Prof C H The History of Belfast Shipbuilding 'Journal Stat Soc. Ireland,' XII 417–434 1911

SAMUEL, JOHN S Juvenile Employment 'Proc Glasgow Royal Phil Soc' XLII. 1–9 1911

STANUELL, CHARLES A The Report of the Vice-Regal Commission upon Irish Railways 'Journal Stat Soc Ireland,' XII 401–416 1911

THOMPSON, Sir WM J The Development of the Irish Census, and its National Importance 'Journal Stat Soc Ireland,' XII 474–488 1911

VERNEY, H Industrial Accidents 'Trans Manchester Stat Soc. 1910–1911, 17–79 1911

WEBB, SIDNEY The Economics of the Existing (or of any) Poor Law 'Trans Manchester Stat Soc 1910–1911,' 1–15 1911

WIGG, T J Notes on the Herring Fishery of 1910 'Trans Norfolk and Norwich Nat Soc' 272–274 1911

Section G—ENGINEERING

ABELL, Prof W S Ship-Model Experiment Tanks their purpose and application 'Trans Liverpool Eng Soc' XXXII 11–25 1911

ALCOCK F (N Staff Inst Eng) A Device for preventing Accidents owing to the Breakage of the Winding-rope 'Trans Inst Min Eng XLI 379–380 1911

ALLEN, EDWARD Inaugural Address The Liverpool United Gas Light Company 'Trans Liverpool Eng Soc' XXXII 1–9 1911

BAIRD, DUGALD (Min Inst Scotland) Wire Ropes as applied to Mining 'Trans Inst Min Eng' XLII 129–138 1911

BEACH, THOMAS (Midland Inst Eng) The Shaw Hemsworth Overwinder 'Trans Inst Min Eng' XLII 92–98 1911

BLACK, JAMES (Min Inst Scotland) Overwinding-prevention and Controlling Gear for Colliery Winding engines, with a Description of the Inglis Controller 'Trans Inst. Min Eng' XLIII 243–247 1912

BREW, J B Some Machinery for the Manufacture of Sugar from the Sugar Cane 'Trans Liverpool Eng Soc' XXXII 286–312 1911

BRIGGS, HENRY (Min Inst Scotland) Testing for Fire damp and Black damp by means of a Safety lamp 'Trans Inst Min Eng' XLIII 64–77 1912

BULMAN, H F, and W B WILSON (N England Inst Eng) Miners' Baths 'Trans Inst Min Eng' XLIII 92–107 1912

BURY, ERNEST The Otto Hilgenstock Direct-recovery Process and its Application 'Trans Inst Min Eng' XLI 531–542 1911

CATTERSON SMITH, J K The Manufacture of Turbo Electric Generators, and some of their Applications to Marine Work 'Trans Liverpool Eng Soc' XXXII 195–231 1911

CHORLTON, ALAN E L (Midland Inst Eng) Methods of Driving by Gas engines for Collieries 'Trans Inst Min Eng' XLII 315–342 1912

CLARK, F BERNARD (S Staff and Warw Inst Eng) High tension Mining Switch-gear 'Trans Inst Min Eng' XLI 394–416 1911

COULSTON, P BARRETT (Manchester Geol Min Soc) Should Exhaust-steam be wasted? 'Trans Inst Min Eng' XLII 443–448 1912

EADIE, J C (Manchester Geol Min Soc) Luminous Electric Mine-shaft Signalling 'Trans Inst Min Eng' XLII 37–41 1911

EDEN, E M A New Steam Trap 'Proc Univ of Durham Phil Soc' IV 39–46 1911

GIBSON, R E The Mechanical Transport of Materials in Gas Works 'Trans Liverpool Eng Soc' XXXII 90–118 1911

GLOVER, SAMUEL Developments in Gas Making 'Trans Liverpool Eng Soc' XXXII 241–257 1911

GULLACHSEN, B C (N England Inst Eng) The Working of the Thick Coal Seams of Upper Silesia 'Trans Inst Min Eng' XLI 209–218 1912

HAMILTON, ANDREW The Economics of Steamship Propulsion. 'Trans. Liverpool Eng. Soc.' XXXII. 263–281. 1911

HARRISON, GEORGE B (Manchester Geol Min Soc) Presidential Address Accidents in Mines caused by Falls of Ground 'Trans Inst Min Eng' XLII 260–272 1912

HART DAVIS, HUGH V (Manchester Geol Min Soc) A Dust fuel Boiler and its Uses 'Trans Inst Min Eng' XLIII 112–121 1912

HEPPLEWHITE, W HUTTON (Mid Counties Inst Eng) The Action and Control of differently constituted Coal roofs 'Trans Inst Min Eng' XLII 356–375 1912

LESSING, Dr R Refractory Materials and their Testing 'Trans Liverpool Eng. Soc' XXXII 66–81 1911

LOUIS, Prof HENRY On the Mutual Developments of Metallurgy and Engineering 'Proc Univ of Durham Phil Soc' IV 46–62 1911

MAVOR, SAM Reduction, Control, and Collection of Coal-dust in Mines 'Trans. Inst Min Eng' XLII 496–524 1912

MORROW, Dr J The Elastic Deflection of Steam Turbine Rotors 'Proc Univ of Durham Phil Soc' IV 147–151 1912

PAUL, JOHN (Min Inst Scotland) The Walker Overwinding-prevention Gear for Colliery Engines, as fitted at the Mary Pit of the Lochgelly Iron and Coal Company, Limited 'Trans Inst Min Eng' XLII 308–312 1912

PICKERING, W H, and GRANVILLE POOLE Notes on Contrivances designed to prevent Overwinding, with some Instances of their Failure 'Trans Inst. Min Eng' XLI 496–505 1911

PIGOTT, N F P The Testing of Metals, Chains, and Ropes 'Trans Liverpool Eng Soc' XXXII 340–354 1911

RALPH, GEORGE J (N Eng Inst Eng) The Holmes-Ralph Gas detecting Portable Electric Lamp 'Trans Inst Min Eng' XLII 201–206 1911

RIDSDALE, HAROLD H (S Staff and Warw Inst Eng) Coal face Conveyers 'Trans Inst Min Eng' XLII 391–406 1912

ROWAN, HENRY (Min Inst Scotland) An Outburst of Coal and Fire-damp at Valleyfield Colliery, Newmills, Fife 'Trans Inst Min Eng' XLII 50–52 1911

SNAPE, WOOD DEANE (Manchester Geol Min Soc) The Pape Miners' Electric Safety-lamp 'Trans Inst Min Eng' XLII 255–257 1912

SNEDDON, J BALFOUR (Min Inst Scotland) Description of the Aerial Ropeway from the Shale-mines to the Oil-works at Oakbank, Mid-Calder 'Trans Inst Min Eng' XLII 300–307 1912

TAITE, CHARLES D (Manchester Geol Min Soc) The Lancashire Electric Power Company's System, and its Application to Lancashire Collieries 'Trans Inst Min Eng' XLIII 168–177 1912

THOMAS, A ERNEST The Mining Industry of Western Australia 'Report Royal Cornwall Poly Soc' I (N S) 500–515 1911

THORNTON, Prof W M (N England Inst Eng) Experiments on Liquid Mixtures for Laying Coal-dust 'Trans Inst Min Eng' XLII 66–82 1911

THURSTON, A P Flying Machines and their Stability 'South-Eastern Naturalist for 1911,' 31–34 1911

WILSON, WILLIAM BRUMWELL (N England Inst Eng) The Advantages of Freezing as a Method of Sinking through heavily-watered or difficult ground 'Trans Inst Min Eng' XLI 349–357 1911

YATES, H JAMES Coal Gas as a Fuel 'Trans Liverpool Eng Soc' XXXII 141–166 1911

Section H —ANTHROPOLOGY

BIDEN, C LEO, and Rev H KLING The Funeral Ceremonies of the Hottentots 'Trans Royal Soc of S Africa,' II 223–225 1912

BULLEID, ARTHUR, and H ST G GRAY Meare Lake Village 'Proc Somersetshire Arch N. H Soc' LVII 42–46 1912

CARDEW, CORNELIUS E Flint Axe head from St Enoder Parish 'Journal Royal Inst of Cornwall,' XIX 140–142 1912

CROOKE, W Presidential Address [The Importance of Anthropological Investigation] 'Proc Cotteswold Nat Field Club,' XVII 141–156 1911.

GRAY, H ST GEORGE Notes on Roman Remains found at Puckington 'Proc Somersetshire Arch N H Soc' LVII 91–97 1912

GRIEVE, SYMINGTON Griddle or Greidell Ine or Een, otherwise known as Griadal Fhinn. 'Trans. Edinburgh F. N. Mic. Soc.' VI. 279–295. 1911.

MEYRICK, E Anthropometrical Report 'Report Marlb Coll N. H Soc' No. 59, 77–102. 1911.
MOIR, J. REID The Flint Implements of Sub-Crag Man 'Proc Prehistoric Soc of East Anglia,' I 17–24. 1911.
MORTIMER, the late J R Notes on the Stature, &c, of our Ancestors in East Yorkshire. 'The Naturalist for 1911,' 313–317 1911
PLATT, S S Stone Celt or Axe found at Castle Hill, Rochdale 'Trans Rochdale Lit. Sci. Soc' x 22–25 1911
PREHISTORIC SOCIETY OF EAST ANGLIA Report on Sub-Crag Implements 'Proc Prehistoric Soc of East Anglia,' I. 24–43 1911
READER, FRANCIS W A Neolithic Floor in the Bed of the Crouch River, and other Discoveries near Rayleigh, Essex 'Essex Naturalist,' XVI 249–264 1911
REID, R C Report on Excavations of a Camp at Mouswald 'Trans. Dumfriesshire and Galloway N H A Soc' XXIII. 310–312 1911
STEAD, Rev W. J. V The Hittites. 'Trans Rochdale Lit Sci Soc' x 49–68. 1911.
STURGE, Dr W ALLEN Presidential Address [Prehistoric Man] 'Proc Prehistoric Soc of East Anglia,' I 9–16 1911
—— The Chronology of the Stone Age 'Proc Prehistoric Soc of East Anglia,' I. 43–105. 1911
SWYNNERTON, FREDERICK The Earliest Inhabitants of the Isle of Man 'Proc. Isle of Man N H A Soc.' I 401–410 1911
UNDERWOOD, Lieut.-Col W Animistic Forms in certain Flints, showing Human Work 'Proc Prehistoric Soc of East Anglia,' I 106–108 1911
WARREN, S HAZZLEDINE On a Prehistoric Interment near Walton-on-the Naze, with a preliminary Report on the Skeleton by Prof A Keith 'Essex Naturalist,' XVI 198–208 1911.
—— On the Correlation of the Prehistoric 'Floor' at Hullbridge with similar Beds elsewhere. 'Essex Naturalist,' XVI 265–282 1911
WOOD, BUTLER. Prehistoric Remains in the Shipley Glen District 'Bradford Scientific Journal,' III. 129–136 1911

Section I—PHYSIOLOGY.

PAGET, STEPHEN The Life of Pasteur 'Trans Ealing Sci. Mic Soc 1910 1911,' 3–6 1911.
ROSS, Dr J MAXWELL. The Weather of 1910 in relation to Health 'Trans. Dumfriesshire and Galloway N H A Soc' XXIII 255–263 1911
SILLS, SPENCER Presidential Address The Study of Nature in relation to Everyday Life 'Rochester Naturalist,' IV 237–250. 1912
STURROCK, Dr. JAMES P The Modern Aspects of Eugenics 'Trans Perthshire Soc. Nat. Sci' v. 83–94. 1911
THEILER, Dr ARNOLD Some Observations concerning the Transmission of East Coast Fever by Ticks 'Trans. Royal Soc of S Africa,' II 319–338 1912.
TOPPING, T Enemies of Public Health 'Rochester Naturalist,' IV 207–218, 221–228 1911.

Section K.—BOTANY

AIKEN, Rev. J. J. M L. Glenquay Moss, Dollar 'History Berwickshire Nat Club,' XXI. 211–213 1911
AITKEN, ROBERT J Native Varieties of Ranunculus. 'History Berwickshire Nat Club,' XXI. 108–110 1911.
ANDREWS, F. W. The Shrubs and Herbaceous Plants of New Zealand 'Trans Burton-on-Trent N H A Soc.' VI. 22–28. 1911.
ARCHIBALD, STEWART. The Weeds of a Garden 'Trans Edinburgh F N Mic. Soc.' VI. 317–323. 1911.
ARNOTT, S. Local Plant Names. 'Trans. Dumfriesshire and Galloway N. H. A Soc.' XXIII. 195–201. 1911.
BAKER, J G. New Plant Localities in North-east Yorkshire. 'The Naturalist for 1911,' 309. 1911.
BARCLAY, WILLIAM. Presidential Address: Our Native Hybrid Roses. 'Proc Perthshire Soc. Nat. Sci.' v. CXII.–CXVII. 1911.

Bennett, Arthur. *Epipactis atrorubens*, a little-known Norfolk Orchid. 'Trans. Norfolk and Norwich Nat Soc.' ix 187–189 1911.
—— *Œnanthe pimpinelloides*, Linn 'Trans Norfolk and Norwich Nat. Soc.' ix. 190–191 1911
Bloomfield, Rev. E. N (assisted by E. W. Swanton) Sussex Fungi. Part I Supplement. 'Hastings and East Sussex Naturalist,' i 300–303 1911
Boudier, Emile. Note sur le Pseudophacidium Smithianum 'Trans British Mycological Soc.' iii 324 1912
Boulger, G S The Hertfordshire Elms 'South-Eastern Naturalist for 1911,' 27–30 1911
Boyd, D A. Notes on Parasitic Ascomycetes Part I 'Trans Edinburgh F N. Mic Soc' vi 333–340 1911
—— Microfungi observed near Kirkcaldy and Fushiebridge 'Trans. Edinburgh F. N. Mic Soc.' vi 342–343 1911
—— Mycological Notes 'Glasgow Naturalist,' iv. 14–18, 85–88. 1911, 1912
British Mycological Society Report of the Teesdale Foray, June 2–6, 1911, and complete List of the Fungi and Mycetozoa gathered 'Trans British Mycological Soc' iii. 291–297 1912
—— Report of the Taunton Foray, Sept. 18–23, 1911, and complete List of the Fungi and Mycetozoa gathered during the Foray 'Trans. British Mycological Soc' iii 298–309 1912.
Brown, N E Some Notes on Seeds as Microscopic Objects. 'Journal Quekett Mic Club,' xi 307–312 1911
Buller, Prof A H R The Production and Liberation of Spores in the Genus Coprinus 'Trans British Mycological Soc' iii 348–350 1912.
Burrell, W H, and W G Clarke The Fauna and Flora of Flordon Common. 'Trans Norfolk and Norwich Nat Soc' ix 170–186. 1911
—— Botanical Rambles in West Norfolk, with Notes on the Genus *Utricularia*. 'Trans Norfolk and Norwich Nat Soc' ix. 263–268 1911.
Burton, James. Notes on Algæ collected in 1911. 'Journal Quekett Mic. Club,' xi 435–440 1912
Burtt-Davy, J Observations on the Inheritance of Characters in *Zea Mays*, Linn. 'Trans Royal Soc of S Africa,' ii 261–270 1912.
Caradoc and Severn Valley Field Club Botanical Notes, 1911. 'Record of Bare Facts,' No 21, 5–12 1912
Carr, J W The Mycetozoa of Nottinghamshire 'Report Nottingham Nat Soc. 1910–11,' 21–29 1912
Cheetham, C A. Some Mosses new to the West Riding, &c. 'The Naturalist for 1911,' 231–232 1911.
Colgan, Nathaniel. On the Inheritance of Pitted Leaf-blotchings in *Arum maculatum*, and on Floral Variations in the Species 'Irish Naturalist,' xx 210–217 1911
—— The Burnt Ground Flora of Killiney Hill 'Irish Naturalist,' xxi 72–76 1912
Cotton, A D On the Structure and Systematic Position of *Sparassis* 'Trans British Mycological Soc' iii 333-339 1912
Crossland, C. Fungus Foray at Sandsend 'The Naturalist for 1911,' 387–393 1911.
—— Recently discovered Fungi in Yorkshire 'The Naturalist for 1912,' 85–92 1912.
Dixon, H N Notes on some Aquatic Plants. 'Journal Northants N H Soc' xvi 89–91 1911
—— Northamptonshire Hepaticæ. 'Journal Northants N. H Soc.' xvi. 109–110. 1912.
Druce, G Claridge. Botanists on the Pennines. 'The Naturalist for 1911,' 322–323 1911
—— The British Utriculariæ. 'Irish Naturalist,' xx 117–123. 1911.
—— *Ulmus Plotti*, Druce 'Report Ashmolean Nat Hist Soc 1911,' 33–35. 1912.
Ewing, Peter. The Summit-Flora of the Breadalbane Range 'Glasgow Naturalist,' iv 48–62 1912
Fordham, W. J. On the Occurrence of *Pedicularis palustris* L en masse. 'The Naturalist for 1911,' 254–256. 1911.
Fullerton, M. B. Notes on Algæ found in the Midsummer Meadow Bathing Place. 'Journal Northants N H. Soc.' xvi. 111–117 1912

GIBB, ROBERT SHIRRA Presidential Address Natural Pasture-lands, and how they become botanically altered by Age and Treatment 'History Berwickshire Nat. Club,' XXI 1–14 1911
GLADSTONE, H S Note on an Ancient Ash Tree near Dalswinton House, known as 'Cummin's Ash' 'Trans Dumfriesshire and Galloway N H A Soc' XXIII 214–216 1911
GRIFFITHS, B MILLARD The Algæ of Stanklin Pool, Worcestershire, an Account of their Distribution and Periodicity 'Proc Birmingham N H Phil Soc.' XII. No. 5, 1–23. 1912.
GROVE, W B Fungi from the Antrim Coast 'Irish Naturalist,' XX 142 1911
—— Fungi from Co Antrim 'Irish Naturalist,' XX 181 1911
INGHAM, W Mosses and Hepatics at Castleton, N Yorks 'The Naturalist for 1911,' 248. 1911
INNOCENT, C F A Century's Changes in the Sheffield District Flora 'The Naturalist for 1911,' 216–221 1911
JOHNSON, GILBERT Respiration and Transpiration in Plants 'Trans Caradoc and Severn Valley F C' V 250–254 1912
JOHNSON, J W H *Amphipora paludosa* W Sm as a West Riding Diatom. 'The Naturalist for 1911,' 359–360 1911
—— Fungi found in Polluted West Riding Streams and other places 'The Naturalist for 1911,' 404–405 1911
JOHNSTONE, R. B, and D A BOYD Report on Fungus Forays, 1911 'Glasgow Naturalist,' IV 10 1911
JONES, R W The Plants of the Sand Dunes 'Proc Llandudno and District F C 1909–10,' 130–133 1912
KNOWLES, M. C Notes on West Galway Lichens 'Irish Naturalist,' XXI 29–36. 1912
LEE, JOHN R Additions to the List of Mosses of Dumbartonshire 'Glasgow Naturalist,' IV 11–14 1911
LINCOLNSHIRE NATURALISTS' UNION Additions and Corrections to the Check List of Lincolnshire Plants, 1909 'Trans Lincolnshire Nat Union, 1911,' 290–299 1912
LINDSAY, JOHN A Rare British Freshwater Alga 'Trans Edinburgh F N Mic Soc' VI 310–316 1911
LOWE, HARFORD J Economy in Plant Life 'Journal Torquay N H Soc' I 157–162 1912
LUCAS, W J Bracken (*Pteris aquilina*) 'Proc South London Ent and N H Soc' 1911–12, 1–5 1912
M'ANDREW, JAMES Notes on the Hepaticae and Mosses of the Three South-Western Counties of Scotland 'Trans Dumfriesshire and Galloway N H A Soc' XXIII 306–309 1911
M'KEEVER, F L A Contribution to the Alga-Flora of Mid-Lothian 'Trans Edinburgh F N Mic Soc' VI 354–372 1911
—— Further Note on the Algæ of the Elf Loch 'Trans Edinburgh F N Mic Soc' VI 372–374 1911
MARLOTH, Dr R Some New South African Succulents and other Plants 'Trans Royal Soc of S Africa,' II 237–241 1912
MASSEE, GEORGE *Evonymus* Mildew 'Proc Bournemouth Nat Sci Soc' III 81–82 1912
MELLOR, A EVELYN The Seedling Structure of *Dryas octopetala* 'The Naturalist for 1911,' 310–311. 1911.
MENZIES, J Some Discomycetes of the Locality and their Habitats 'Trans Perthshire Soc Nat Sci' V 75–83 1911
MERLIN, A A C ELIOT Notes on a Photograph of the Secondary Structure of *Navicula Smithii* 'Journal Quekett Mic Club,' XI 443–444 1912
MEYRICK, E Report of the Botanical Section 'Report Marlb Coll N H Soc.' No 59, 25–33 1911
MORRIS, Rev. A C Notes on the recent Occurrence of certain Plants in Wanstead Park, Essex 'Essex Naturalist,' XVI 228–231 1911
NICHOLSON, CHARLES Notes on Alien and Casual Plants in the Neighbourhood of Walthamstow and Woodford, Essex 'Essex Naturalist,' XVI 209–216 1911
—— The Service Trees 'Selborne Magazine,' XXII 148–150 1911
NICHOLSON, W. E. The Hepatics of Sussex. 'Hastings and East Sussex Naturalist,' I. 243–292. 1911.

NORRIS, F. DE LA MARE The Cystidia of *Coprinus comatus*. 'Proc. Bristol Nat. Soc' III Part I 28-29 1911

NOWERS, J E Noted Oaks near Burton 'Trans Burton-on-Trent N H A Soc.' VI 18-21 1911

PATERSON, JOHN Destruction of Timber in the Storm of 5th November, 1911 'Glasgow Naturalist,' IV. 5-7 1911

PETCH, T European Fungi in the Tropics 'Trans British Mycological Soc.' III 340-347 1912

PHILIP, R H The Uredineæ 'The Naturalist for 1911,' 382-386 1911

PHILLIPS, E P A Note on the principal Systematic Work and Publications dealing with the South African Proteaceæ 'Trans Royal Soc S Africa,' II 275-282 1912

PRAEGER, R. LLOYD Notes on the Flora of Inishbofin 'Irish Naturalist,' XX 165-172 1911.

—— A Note on Dooaghtry 'Irish Naturalist,' XX 193-194 1911

—— The Survey of Clare Island Report of Progress during 1911. 'Irish Naturalist,' XXI 39-41 1912

PRIESTLEY, J H The Pelophilous Formation of the Left Bank of the Severn Estuary 'Proc Bristol Nat Soc' III Part I 9-25 1911

RAMSBOTTOM, J Work published during 1911 on the Cytology of Fungus Reproduction 'Trans British Mycological Soc' III 354-365 1912

RAYNER, J F Guide to the Fungi and Mycetozoa of the New Forest 'Proc Bournemouth Nat Sci Soc' III 105-155 1912

REA, CARLETON British Geasters 'Trans British Mycological Soc' III 351-353. 1912

—— New and Rare British Fungi 'Trans British Mycological Soc' III 376-380 1912

REID, CLEMENT The Relation of the Present Plant Population of the British Isles to the Glacial Period 'The Naturalist for 1911,' 373-379 1911, 'Irish Naturalist,' XX 201-209 1911

RENWICK, JOHN Notes on the Ash Trees (*Fraxinus excelsior*, L) of the Clyde Drainage Area 'Glasgow Naturalist,' III 105-114 1911

—— Large Grey Poplars (*Populus canescens*, Lin) at Mauldslie Castle 'Glasgow Naturalist,' III 119-120. 1911

—— and RICHARD M'KAY Table of Measurements of Ash Trees in the Clyde Drainage Area 'Glasgow Naturalist,' III 115-118 1911

RICHARDSON, NELSON M Report on the First Appearances of Birds, Insects, &c, and First Flowering of Plants in Dorset during 1910 'Proc Dorset N H A F C' XXXII 239-248 1911

RIDDELSDELL, Rev H J. Report (No 3) on the Progress made in connection with the Flora of Gloucestershire 'Proc Cotteswold Nat Field Club,' XVII 279-281 1911

RIDGE, W T BOYDON Botanical Report 'Trans N Staffs F C' XLVI 112-120 1912

ROPER, Miss IDA M The Flower of Bristowe 'Proc Bristol Nat Soc' II Part III 5-8 1911

SALMON, Prof E S Presidential Address Economic Mycology and some of its Problems 'Trans British Mycological Soc' III 310-324 1912

SANDERSON, A R, and C A CHEETHAM Notes from the West Coast 'Irish Naturalist,' XXI 54-55 1912

SCOTT, Dr D H Presidential Address The Seed plants of the Coal 'Proc Bournemouth Nat Sci Soc' III 26-31 1912

SMITH, Miss A LORRAIN An Alien Species *Xylobotryum caespitosum* A L Sm 'Trans British Mycological Soc' III 331-332 1912

—— New or Rare Microfungi 'Trans British Mycological Soc' III 366-374 1912

THOMAS, Miss C G Devices to ensure Cross Pollination in Plants 'Trans Caradoc and Severn Valley F C' V 244-245 1912

THOMAS, H HAMSHAW Recent Researches on the Jurassic Plants of Yorkshire. 'The Naturalist for 1911,' 409-410 1911

TODD, WILLIAM A Wild Flowers of Sheen Common 'Selborne Magazine,' XXII 147-148. 1911

TROW, Dr. A. H (edited by) The Flora of Glamorgan Section IV.—Incompletæ. 'Trans. Cardiff Nat. Soc.' XLIII. 147-194. 1911.

WAGER, HAROLD. The Study of Fungi by Local Natural History Societies. 'The Naturalist for 1911,' 351–356. 1911, 'Trans British Mycological Soc.' III 325–330 1912.
WATT, LAURENCE Notes on Plants from the Vice-Counties of Lanark (77), Banff (94), and Dumbarton (99) 'Glasgow Naturalist,' IV. 81–85. 1912.
WHELLENS, W. H Arboriculture as a Hobby 'Trans Dumfriesshire and Galloway N H A Soc' XXIII. 284–291 1911
WHITE, JAMES W Bristol Botany, 1910 'Proc Bristol Nat Soc.' II Part III 22–31. 1911.

Section L.—EDUCATIONAL SCIENCE

FINDLAY, Prof J J. Recent London Experiments in the Schooling of Poor Children. 'Trans Manchester Stat Soc. 1910–1911,' 89–102 1911
MCMASTER, Dr A B Notes on School Children. 'Trans Rochdale Lit Sci Soc' X 69–79 1911
MONTGOMERY, J Education and Commerce 'Proc Glasgow Roy Phil Soc' XLII 111–124 1911

Section M.—AGRICULTURE

BORLASE, W. The Study of Agricultural Seeds. 'Report Royal Cornwall Poly. Soc' I (N S) 516–523 1911.

OBITUARY.

BEDDOE, Dr JOHN By J Hambley Rowe. 'Bradford Scientific Journal,' III 143–145. 1911
—— By G Parker 'Proc Bristol Nat Soc' III Part I. 7–8 1911
BURTON, F M 'Trans Lincolnshire Nat. Union, 1911,' 317 1912
CAPPER, SAMUEL JAMES By G T P[orritt]. 'The Naturalist for 1912,' 93–94 1912
COLE, Rev E MAULE By T. S[heppard] 'Proc Yorkshire Geol. Soc' XVII. 256–257. 1912
DIXON, Dr JAMES STEDMAN 'Trans Inst Min Eng' XLII 48–49 1911.
FOWLER, Canon W By E A W[oodruffe]-P[eacock]. 'Trans Lincolnshire Nat Union, 1911,' 316, 1912; 'The Naturalist for 1912,' 121–123, 1912
HOOKER, Sir JOSEPH DALTON By H N Dixon 'Journal Northants N H Soc. XVI 162–163 1912
KLAASSEN, H M 'Proc Croydon N H Sci Soc 1910–1911,' xlv 1911
LEE, PHINEAS FOX By T. W. W 'The Naturalist for 1912,' 123–125 1912
MORTIMER, JOHN ROBERT By T S[heppard] 'The Naturalist for 1911,' 329–330. 1911.
—— By G W Lamplugh. 'Proc Yorkshire Geol Soc' XVII. 258–260 1912
PEACH, CHARLES WILLIAM. By F Hamilton Davey 'Report Royal Cornwall Poly. Soc' I (N S) 469–499 1911
PHILIP, ROBERT H By T. S[heppard] 'The Naturalist for 1912,' 150–151. 1912
PLOWRIGHT, Dr. CHARLES BAGGE By T. P. 'Trans Norfolk and Norwich Nat. Soc.' IX. 275–282 1911.
SIMPSON, THOMAS 'Report Ealing Sci. Mic. Soc 1910–1911,' XIII–XIV. 1911.
STEWART, SAMUEL ALEXANDER. By Rev. C. H. Waddell. 'Proc. Belfast Nat. F. C.' VI. 410–422 1912.
TUTT, J. W. 'South-Eastern Naturalist for 1911,' xli–xlii. 1911.

APPENDIX II

A Report on Solubility Part II

By J. VARGAS EYRE, *M.A*, *PhD*

[Ordered by the General Committee to be printed *in extenso*]

I INTRODUCTION

In this Report a brief account is given of the various researches on solubility that have been published, and the main conclusions arrived at, in so far as they have a bearing on the general subject The matter is arranged chronologically and as far as possible according to subject

A systematic study of the literature was commenced in 1908, and Part I of this Report, relating to the period 1790 to 1895, was presented at the Sheffield Meeting in 1910, the work published up to and during 1911 is summarised in this second part All references are made to the original papers, which have been consulted in nearly every case quoted The scheme of classification followed is that adopted in Part I.

It is quite remarkable how much attention has been devoted to the study of solutions during the past fifteen years, and how views which differ fundamentally have been developed regarding the phenomena Taken as a whole, the trend of recent research is to show that the dissolution of a substance involves far greater changes than the mere dissemination either of its particles (molecules) or of their constituent parts (ions) among the inert particles of solvent, moreover, in the light of recent observations, it is not possible to regard solvents, especially in the case of water, as inert media acting merely as diluents The recognition of this circumstance, together with a more careful study of the facts said to justify the application of the *ionic dissociation hypothesis* to solubility problems, have necessitated a fundamental change of view It is probable that, at no distant date, the use of the term "ion" in connection with solution problems may

be conveniently dropped as a help towards understanding the cause of dissolution and the condition in which a substance exists in solution.

As evidence is accumulated from the study of the subject on broad lines and the behaviour of non-aqueous solvents becomes better understood, the necessity arises of regarding dissolution as primarily a chemical process in which both solvent and solute undergo change and rearrangement: a change which, besides involving their reciprocal interaction, includes their degradation into simple molecules.

II.—Methods of Determination.

In Part I. of this Report (Sheffield, 1910) the attention of authors was directed to the importance of placing on record a brief but exact description of their methods of working when publishing the results of solubility measurements. If quantitative work on this subject is to be of value to later investigators, it is absolutely necessary that the limits of accuracy should be made known. Only from such knowledge is it possible to judge whether legitimate use may be made of published data in any subsequent research.

Within the scope of this Report it is not possible to refer to all the different methods of determining solubility which have been made use of from time to time: much necessarily depends upon the properties of both solvent and solute, and upon the temperature and pressure at which measurements are made. It is thought to be sufficient to include in this section only methods of more or less general application and those which present useful elements of novelty.

A.—*Solubility of Solids.*

When studying the solubility of solid substances in gases, earlier investigators made use of a modified form of Andrew's apparatus.*

1897 In the research on this subject carried out by *Talmadge*[37] the following method was adopted. A saturated solution of the solute (camphor) in the solvent (ether) was distilled from a flask connected to a condenser to which was attached a receiving vessel in connection with a pump and manometer; the solvent was heated slowly to the desired temperature, and the distillate, collected under reduced pressure, was analysed by a refractrometric method.

It is sometimes stated that difficulty is experienced in preparing saturated solutions of a salt in the solution of another salt: this was noticed particularly by *Lowenherz*[26] when determining the solubility of potassium sulphate in solutions of magnesium chloride. He emphasised the necessity of heating the solution above the temperature at which determinations are to be made and then allowing it to cool, because the potassium salt dissolves only with difficulty in the solution of the magnesium salt.

A modified form of "Beckman apparatus" has been described by *Meyerhoffer*,[25] the new form being available either for determinations of freezing point or for solubility measurements.

In the same year, a somewhat complicated form of apparatus was

* *Vide* Part I., R. 80.

described by *Gockel*[31] for determining solubility in boiling liquids. This involved forcing the boiling solution by pressure through a filter into a weighed flask fitted by means of an adapter to a reflux condenser; the solution so collected was weighed and analysed. The filter through which the hot solution passes was made in the form of a condenser kept hot by a jacket of water a few degrees above the boiling-point of the solution.

1898 When studying the rate at which substances dissolve, *Noyes and Whitney*[42, 51] used the solute in the form of sticks varying in superficial area, and caused these to be rotated in small flasks.

A very efficacious method of preparing saturated solutions is described by *Koehler and Martini*,[54A] involving the agitation of solute and solvent together in a tube fitted with a glass stirrer made in the form of an Archimedes screw, a form of stirrer now very generally used.

1899 *Pawlewski*[55] prepared saturated solutions at temperatures ranging from 0° to 100° C. by agitating solvent and solute together in a tube, the agitation being effected by drawing a current of air through the liquid. The tube and also a weighed receiving flask were immersed in water at the required temperature, and were so connected together that a sample of the saturated solution could be transferred to the flask by suction whilst still immersed in the water-bath.

1900 In the following year *Hopkins*[82] suggested a more novel method of preparing saturated solutions. Placing solvent and solute together in a tall cylinder, by a simple device he pumped the more concentrated liquor continuously up from the bottom of the cylinder and projected it on to the weaker solution above.

1901 *Immerwahr*[113] studied the solubility of precipitates containing heavy metals by measuring the potential differences between electrodes of those metals—such as mercury, copper, lead, cadmium, and zinc—and the saturated solutions of their less soluble salts, the saturated solutions being obtained by precipitating salts of the metals with excess of the precipitant. The concentration of the 'ions' of the heavy metal in solution was calculated from the potential difference, and since the same excess of precipitant was used in all cases, the potential differences were regarded as being proportional to the solubilities of the salts.

1902 The work of *Noyes and Kohr*[142] casts doubt on the validity of the electrical conductivity method as a means of determining the solubility of substances. These authors base their contention on their own estimation of the solubility of silver chloride in aqueous solutions of potassium chloride and hydroxide. The results which they arrived at by direct analysis led to the conclusion that silver hydroxide is dissociated only to the extent of 70 per cent., whereas Kohlrausch, when determining the solubility of silver chloride by the conductivity method, assumed it to be completely dissociated. The solubility of sparingly soluble

1903 salts was also studied by *Abegg and Cox*,[167] who determined the solubility of certain silver salts by measuring the potential differ-

ence at electrodes of the type Ag/AgX, $^{N}/_{10}$MX, when AgX is the silver salt and MX a soluble salt of the metal M with the same anion. for MX the following substances were taken: KBr, KCNS, KCl, ½ Ba $(OH)_2$, ½ Na_2CO_3, ½ K_2CrO_4, and ½ $Na_2B_4O_7$. From the results obtained the solubility of AgX was calculated in accordance with Nernst's theorem * The conductivity method has been used by *Bottger* [169] in determining the solubility of sparingly soluble salts he has published full details of the method and of the precautions necessary to be observed

1904. A full description was given by *Cantoni* [212] of an apparatus for determining the solubility of salts in solvents other than water

When measuring solubility at any particular temperature the *Earl of Berkeley* [213] took the precaution to make observations at 1° above and at 1° below the required temperature, and to take the mean of those results He also designed a special form of apparatus for determining the solubility of salts and the density of their saturated solutions at the boiling point

1905. When measuring the solubility of ammonium nitrate in various aqueous alcoholic solutions *Fleckenstein* [213] dissolved known weights of salt in known weights of solvent, and observed the temperature at which the solute began to crystallise

1906 *Veimarn* [284] described an apparatus whereby the solubility of solids in liquids may be conveniently determined and for which he claimed superiority over other forms it was based on the same principle as that devised by V Meyer, but had several novel features

When determining the solubility of a solid at the eutectic point, *Trautz and Anschutz* [268] slowly cooled the solution saturated at 0°C and analysed the last liquid fraction This fraction was frozen and then partly thawed and the melted portion analysed In the case of a true eutectic the results of the two analyses should agree

The solubility of salt mixtures at temperatures above the boiling points of their saturated solutions was determined by *Thiele and Calberla* [285] The mixed salts were dissolved in water in one chamber of a specially constructed closed tube which was maintained at constant temperature by superheated steam, the solution, when saturated, was filtered into a second chamber of the same closed tube, was slowly cooled, restored to ordinary pressure, and then analysed

Hartley and Thomas [259] used a closed-tube method, similar to that previously adopted by *Kuriloff* [28A], in determining the solubility of triphenylmethane in organic solvents Weighed quantities of solvent and solute were enclosed in small tubes, and these were then heated and the temperature observed at which the last crystal was (*a*) just growing and (*b*) just dissolving The mean of many such observations of temperature was taken as being the temperature of saturation

1907 The ultramicroscope has been brought into use by *Biltz* [289] in determining the solubility of sparingly soluble substances With the aid of this instrument it was found possible to determine the degree of dilution at which two solutions no longer give a precipitate when mixed, and in this manner to determine the solubility of the precipitate

* *Vide* Part I, R 141.

which forms on admixture of stronger solutions In general, the values thus determined—for instance, for AgCl and AgBr—are higher than those obtained by the conductivity method

In determining the solubility of stearic acid in ethylic alcohol, *Emerson*[302] found it necessary to use a large excess of the solid, otherwise highly supersaturated solutions are formed and constant results are not obtainable

Osaka[313] used a refractometric method in determining the composition of saturated solutions The method depends upon the validity of the relationship $ax + bx^2 = \delta - \delta^1$, in which x is the concentration of the solution, δ and δ^1 are the refractometer readings for the solution and solvent respectively, and a and b *constants* which can be calculated from observations made upon two solutions of known concentration thus, if the refractometer readings be taken for a saturated solution,
1908. the concentration x can be calculated In a subsequent paper the author confirmed the applicability of this refractometric method[338]

The solubilities of a large number of sparingly soluble salts were recalculated by *Kohlrausch*[329] from data which had been obtained from conductivity measurements

Hill[331] gave a method for estimating the relative solubilities of two sparingly soluble salts, which, however, depends upon a knowledge of the degree of dissociation of both salts in their saturated solution By this method he determined the relative solubilities of the halides and thiocyanate of silver

Interesting observations were made on the rate of dissolution by *Gaillard*,[324] who found that substances of equal solubility often take widely different times to dissolve

1909 *Schroder*[362] described an apparatus wherewith the solubility of a solid can be measured at the boiling point of the saturated solution, the distinguishing feature being that all junctions were made of fused glass He also described another apparatus for measuring solubility at room temperature which was specially designed to guard against loss due to evaporation of the solvent during filtration

A form of apparatus suitable for use in estimating the solubility of very small quantities of substance was described by *Stolzenberg*[351]

Getman and Wilson[359] tested Osaka's refractometric method of determining solubility, and were only able to obtain approximate results when using sucrose, potassium chloride, bromide, iodide, nitrate and chromate

An apparatus for measuring solubility at high pressures was described by *Cohen and Sinnige*,[355] and in a later paper[356] these authors described the estimation of the solubility of zinc sulphate and cadmium sulphate at different pressures The method used was somewhat novel · cells of the Weston type were set up and the E M F of the cell measured, (1) using in the cell a saturated solution of the salt in question in contact with solid, (2) a saturated solution not in contact with solid, (3) a solution of known concentration The solubility was calculated from the results of these measurements

1911. The following mathematical formula was deduced by *Prud'homme*[416] for calculating the solubility of sparingly soluble salts from conductivity measurements. If V represent the dilution of the salt when ionisation becomes complete, v the dilution of a saturated solution, and Λ_V and Λ_v the respective molecular conductivities at those dilutions, then

$$\Lambda_V - \Lambda_v = \left(\frac{V}{v}\right)^{\frac{1}{n}},$$

in which n is approximately equal to 3·06.

B.—*Solubility of Liquids.*

Change of volume usually occurs when two liquids are mixed

1898 together, and on this fact *Herz*[40] based a method of determining the solubility of liquids in each other. A similar method

1906 was used by *Rex*,[263] by which he estimated the solubility of halogen derivatives of hydrocarbons in water. He shook together known volumes of liquid and water in a graduated vessel, and observed the volumes before and after agitation.

1907 For measuring the reciprocal solubility of liquids *Dubroca*[314] has used the method of heating known weights of two liquids together and observing (1) the temperature at which two layers cease to exist, and (2) the temperature at which, on cooling, two layers appear. The mean of these results is taken as the temperature at which the mixture of known composition was stable in presence of its components.

1911. *Grosschuff*[419] determined the solubility of water in various solvents as follows. Known quantities of water and dry solvent were heated together in a closed glass bulb until all the water was dissolved, the bulb was then cooled until a cloud formed within the solution, when it was again warmed and the temperature observed at which the cloudiness disappeared. From such data the solubility was calculated.

C.—*Solubility of Gases.*

During the period dealt with in this part of the Report comparatively little was done which involved the use of gaseous solutes, and for the most part the methods adopted were those which had been used generally in earlier work.

1896 A somewhat novel form of pressure tube was described by *Walter*,[14A] which can be used equally well for determining the solubility of either gaseous or solid substances in liquids at high temperatures and pressures.

1897 *Roth*[29] made use of a form of apparatus which was essentially the same as that suggested by Ostwald, which has been described and used by Timofejeff * and by *Gordon*.†

Slight modifications of this apparatus were sometimes introduced, such, for example, as that used by *Braun*,[74] who reduced the length

* Zeitschr. physikal Chem. [1890], **6**, 141.
† *Ibid.* [1895], **18**, 1.

of the gas burette by having an enlargement blown in the central portion of the tube.

1903 When determining the solubility, under pressure, of oxygen, hydrogen, nitrogen, and carbon monoxide in water, *Casuto*[181] confined the gas in a graduated glass tube, which was connected with a cylindrical bulb containing a known quantity of water kept agitated by a soft iron stirrer controlled by a solenoid

McLauchlan[165] determined the vapour pressure of hydrogen sulphide in solutions of salts by means of a dynamical method, and also the solubility by an analytical method, he obtained accordant results, thereby establishing the validity of Henry's law in these cases

1904 *Knopp*[198] made use of a slightly modified form of the apparatus used by Roth, Timofejeff, and others, but took the precaution of placing the whole apparatus in a suitably large reservoir of water, so as to maintain an equal temperature in all parts of the apparatus

A very exact method of estimating the absorption of purified carbon dioxide by aqueous solutions of various hydrates and carbonates was devised by *Raikov*[219A], this method, as well as those already referred to, was made use of by *Christoff*[253A] when studying the phenomena of absorption of the gas by solutions of other salts in water

1905.

1906 *Hufner*[270A] used a globular absorption vessel provided with an inlet and outlet, the whole constructed of glass This vessel contained the aqueous solution under investigation, which was boiled to free it from occluded air before admitting the gas For the exact details of the various operations the original description * should be consulted

Some of the more recent work on gaseous absorption has been carried out under conditions which admit of remarkable precision being attained The apparatus devised for the purpose, although based on some earlier and simple form, has necessarily become complex and difficult of manipulation Of these, more particularly, mention must be made of the method and apparatus used by *Usher*[368A] in measuring the solubility of carbon dioxide in aqueous solutions of non-electrolytes, and also the apparatus described by *Drucker and Moles*[382] This last-mentioned apparatus was designed for measuring the solubility of gases in small quantities of liquids, it formed the subject of a further publication by *Moles*[397]

1910

An indirect method of determining the solubility of a gas in a liquid was developed by *Jones*[399] If V ccms of air are bubbled slowly through v ccms of a solution containing a grms of a gaseous solute, and if c grms of gas are extracted by the air, then if S represents the solubility coefficient of the gas in the liquid, the following relationship is true :—

$$S = \frac{V}{v \log_e \frac{a}{a+c}}$$

* Archiv f. Anatomie u. Physiologie, Physiolog. Abteilg. 1901, p. 191

III and IV —Influence of Nature of Solvent and Solute.

For many years the attention of investigators of solubility phenomena was devoted almost exclusively to the study of cases in which water was the solvent used A surprising amount of work was done which dealt with aqueous solutions, and the opinion grew up that water as a solvent possessed quite unique properties and was quite distinct from other solvents It was, however, becoming generally recognised that solubility in some way involved the mutual interaction of solvent and solute

With the advent of the 'ionic dissociation hypothesis' and its application to solution, this belief in a special property of water became much strengthened, mainly from the fact that by making certain assumptions it was found possible to treat the problems presented by solutions mathematically, a possibility which was freely exercised by physical chemists Notwithstanding much evidence to the contrary, one of the assumptions made was that the solvent played no part whatever in conditioning solubility, and that therefore the problems could be treated precisely as if the solute diffused into a volume of an inert gas

The need of modifying this hypothesis was soon manifest, the ionised portion of the solute was then regarded as being in combination with the solvent This modification having proved to be insufficient as an explanation of the facts elicited by a study of the problems on broader lines, it was agreed by the promoters of the hypothesis that not only the ionised portion but also the non-ionised portion of the solute must be in combination with the solvent

Now that reciprocal interaction between solvent and solute is a generally accepted proposition as explaining the facts, it becomes a matter of first importance to study solubility phenomena in relation to the properties, both physical and chemical, of the substances concerned

A considerable amount of work having direct bearing on this aspect of the subject has been published, and, following the plan adopted in Part I of this Report, the subject matter has been classified in this Section III according as it relates to the influence of A, the physical nature of the solvent, B, the chemical nature of the solvent

In Section IV A and B a similar classification is adopted with respect to the solute, and an additional subsection C has been included to bring together work relating to solubility as a function of atomic and molecular weights

III A —*Physical*

1896 *Arctowski*[13] measured the solubility of sulphur, bromine, iodine, mercuric iodide, and tin tetraiodide in carbon bisulphide, and of iodine in benzene, chloroform, and ether at temperatures close to the solidifying point of the solvents The results led to the conclusion that the solubility graphs may be prolonged beyond the point of solidification of the solvent, and that this point has no peculiar significance

Arguing from previous work on the velocity with which solid

substances sublime, *Arctowski*[13] came to the conclusion that in order to test the validity of the so-called 'laws of solubility' the simplest case should be studied first—namely, the dissolution of a solid in a gas This he considered to be a case of purely physical dissolution—that is to say, one in which the effect of the solvent is reduced to a minimum He regarded measurements of vapour-tension of solid bodies as measurements of their solubility in the surrounding medium

It was anticipated by *Tolloczko*[7] that optically active solvents would show a preference for optically active solutes, but experiments made with two optically active components of a racemic mixture in equilibrium with water and an active solvent have shown that this is not the case

1902 The solubility of carbon monoxide in binary organic mixtures was studied by *Skirrow*,[128] who observed the existence of a relationship between solubility and the surface tension of the liquid used, mixtures which exhibit a minimum surface tension—for example, benzene and acetic acid—being also found to exhibit a minimum absorption

1903 In the following year interesting observations regarding the physical state of the solvent as conditioning solubility were made by *Centnerszwer and Teletoff*[182] These authors found that substances such as anthracene and anthraquinone are much more soluble in liquid sulphur dioxide at temperatures near its critical point than at lower temperatures The solubilities measured at the critical point were regarded as the mean solubilities in the liquid and in the vapour of the solvent, and depend upon the volume of solvent used If the original volume of liquid taken is large enough, the vapour phase may disappear on heating, in which case the solubility determined is that in the liquid alone

The work of *Andreas Smits*[180] showed that solutions of a solid in a vapour—anthraquinone in ether—can become supersaturated, and that the transition to the stable phase involves passing through a metastable phase—namely, a supersaturated liquid solution

1906 *Winkler*[262] confirmed the rule he had put forward * that the change in the absorption coefficient of a gas is proportional to the change in the internal friction (viscosity) of the solvent In the same year *Christoff*[265] found a relationship between the surface tension of a liquid and its ability to absorb gases Curves were plotted showing the variation in the solubility of the gases H_2, N_2, O_2, CH_4, CO, and CO_2 in sulphuric acid of varying strength, these all showed minima corresponding with the maximum surface tension of the liquid Further, if a number of liquids be arranged in descending order of magnitude of their surface tension, they are then in ascending order of magnitude of their power to absorb carbon monoxide

1907 From a study of the solubility of gases in binary mixtures of organic liquids and the compressibility of the latter, *Ritzel*[294] concluded that the power of a liquid to dissolve a gas is intimately connected with its compressibility; in support of that conclusion he cited Just's work, which showed that the ratio of the

* *Vide* Part I, R. 190

solubilities of carbon monoxide and nitrogen is independent of the solvent.

1910 It was observed by *Findlay and Creighton*[369] that many colloidal suspensions increase the solubility of gases in water, an example being silica, which increases the solubility of carbon dioxide and nitrous oxide—a fact which these authors attributed to the dissolution of the gas in the colloid.

Centnerszwer[378] studied the solubility of various salts, mostly halides, in methylic alcohol at the critical temperature. Potassium iodide was found to be soluble, whilst the chloride was insoluble, though, contrary to the behaviour of the soluble salts, it had no effect in raising the critical temperature of the alcohol. Investigations of solubility above the critical temperature of the solvents were also prosecuted by *Tyrer*,[370] who found that although the solubility of sodium iodide in methylic and ethylic alcohols rapidly decreased as the critical temperature of the solvent was approached, yet, even after the liquid phase had disappeared, a considerable quantity of salt remained dissolved.

The absorption of carbon dioxide in *p*-azoxyphenetole in its three physical states—namely, solid, crystalline liquid, and ordinary liquid—was studied by *Homfray*.[371] He found that the anisotropic liquid phase (145.5° to 166.5°) showed more absorptive power than the solid, but that the ordinary liquid phase, notwithstanding the higher temperature, had a much greater power of absorption than either.

In a paper dealing with the absorption of gases by metals, *Sieverts and Krumbhaar*[368] show that, whereas some gases are more soluble in the solid metal, others dissolve more readily in the liquid metal: for instance, sulphur dioxide dissolves in liquid copper only, hydrogen dissolves in solid copper, nickel, and iron, but is more soluble in these metals when they are in the molten state. Continuing this work,

1911 *Sieverts*[402] concluded that hydrogen gas forms a true solution in these metals, because the solubility is independent of the area of the surface of the metal used.

III. B.—*Chemical.*

1897. In connection with the study of the solubility of solid substances in vapours, *Benedict*[35] observed that the presence of a little ether largely increases the volatility of naphthalene, similar results being obtained with camphor and also when other solvents were used. When repeating this work, *Talmadge*[37] was unable to confirm the above-mentioned result with regard to naphthalene, although he found that the equilibrium between solid and gaseous naphthalene is not independent of the other components of the system.

1898 *Walker and Wood*[41] compared the solubility of the three hydroxybenzenes in water, acetone, ether and benzene. They found that neither the order of solubility of the three isomeric compounds nor their solubility ratio is independent of the solvent.

1899 An extensive study of the properties of liquid ammonia as a solvent was made by *Franklin and Krauss*,[62] who investigated the behaviour of 175 salts and 250 carbon compounds in this solvent;

judging from the large amount of information recorded, there is little well-defined class-behaviour In a similar manner the solubility of a number of salts in acetone and methylal was investigated by *Eidmann* [66]

1901 A comparison of the solubility of carbon dioxide in forty-four different solvents was made by *Just* [95] · glycerol was found to have least solvent power, next came water This author found that in the case of homologous series, the solvent power diminished with increasing molecular weight The solubilities of nitrogen, hydrogen, and carbon monoxide in seventeen different solvents were also measured, and it was observed that when the solvents were arranged in order of solvent power for each of these gases, the arrangement was practically the same as for carbon dioxide.

1902 *Kahlenberg and Schlundt* [138] made an exceptionally complete study of the solvent power of liquid hydrogen cyanide, comparable with the work of Franklin and Krauss on liquid ammonia They found a large number of substances to be soluble in this solvent, some of them, such as potassium iodide, potassium cyanide, sulphur trioxide, and hydrogen sulphate, give good conducting solutions

Speyers [143] compared the solubilities of a number of organic substances in water and in the lower alcohols. no regularity in solubility was observed as the series of alcohols was ascended, and Schroder's * equation was not confirmed

1903. Nitromethane was found by *Bruner* [154] to dissolve antimony trichloride, antimony tribromide, mercuric chloride, tribromacetic and other organic acids, and to be an ionising solvent *Mittasch* [168] found numerous inorganic and partly organic electrolytes to be very sparingly soluble in nickel carbonyl, whilst some non-electrolytes, such as camphor and alcohol, are more soluble

1905. *Fleckenstein* [243] compared the solubility of ammonium nitrate in water with that in methylic and ethylic alcohols, and among other interesting results found that ethylic alcohol diminished the solubility of the salt in water, whilst methylic alcohol increased it

In the same year the solubility of mercuric chloride in ethylic acetate and in acetone was examined by *Aten* [233] *Muller* [246] made the interesting observation that ferrous and ferric hydroxides are readily soluble in glycerol, whilst the hydoxides of aluminium and chromium are only sparingly soluble in that solvent *Schroder* [248] found that pyridine is in many respects comparable with water as a solvent The solubility of zinc hydroxide in alkaline solutions formed the subject of an investigation by *Moir*,[225] and *Buchner* [255] studied the solubility of a large number of organic solids and liquids in liquid carbon dioxide, and he classified them according as they were or were not completely miscible

1906 with the liquefied gas Liquid methylamine was used as a solvent by *Gibbs*,[277] who found that it was a better solvent of organic compounds than liquid ammonia, but not so good a solvent of inorganic compounds. *Ruff and Geisel* [257] experimented with liquid ammonia as a solvent of the metals sodium, potassium, and lithium, and could find no indication of any combination between metal and solvent

* Part I., R. 202 ; *Zeitschr. physikal. Chem.*, 11, 449.

Further addition to the knowledge of solubility of substances in solvents other than water was made by *McIntosh, Archibald, and Steele*,[261] who examined the solubility of organic and inorganic substances in hydrogen halides With the object of throwing light upon the relationship between solvent and solute, *Walden*[266] compared the solubilities of a number of tetralkyl ammonium halides in different solvents In the case of tetramethyl-ammonium iodide he found that the solvent power was greatest in the case of solvents containing hydroxyl groups and increased with (1) the associative power and (2) the dielectric constant of the solvent

1907 The question of the solubility of *d*- and *l*-isomerides in optically active solvents again received attention, this time from *Jones*,[306] who found the solubility of the isomerides in active solvents to be identical with the solubility in inactive solvents In continuation of his work upon the properties of liquid ammonia as a solvent, *Kraus*[303] examined the solubility of the alkali metals in this liquid and also in alkylamines The metals are only soluble in methyl- and in ethyl-amine, not in the higher members of the series *Shinn*[296] also determined the solubility of a number of salts in ethylamine, finding the most soluble to be silver nitrate, lithium chloride, and ammonium chloride

Magri[315] found that although liquid sulphuretted hydrogen does not dissolve salts of strong bases, it is a good solvent of compounds of non-metals amongst themselves, such as sulphur iodide

Van Laar[292] deduced the following general expression for the solubility of any electrolyte in any solvent $c = C\lambda\ (1+\lambda)$, in which c represents concentration in the saturated solution, C the dissociation constant, and λ a constant almost independent of the nature of the

1908. solvent Acetamide was compared with water as a solvent by *Menschutkin*[335], he found a close similarity to exist between these two solvents many salts crystallise with acetamide of crystallisation, and there is a close correspondence between the solubility curves of the hydrates and of the compounds with acetamide Comparing the solubility of tetraethyl ammonium iodide in water and in a number of organic solvents, *Walden*[326] found that if the saturated solution contained n molecules of solute for every N molecules of solvent, then, if S represents the solubility, the following relationship obtained —

$$S = \frac{100\,n}{n+N}$$

He also found that the cube root of the solubility of tetraethyl ammonium iodide in any solvent is nearly proportional to the dielectric constant of the solvent

Herz and Kuhn[337] compared the solubility of various haloid salts of mercury, potassium, sodium, and ammonium in different alcohols, and found that the solubility diminishes as the molecular weight of the alcohol increases

1910. *Dolezalek*[376] concluded, on purely theoretical grounds,* that the ratio of the solubility of two indifferent gases should be the

* *Vide* Section IV. A.

same for different solvents: a 'law' which had previously been discovered experimentally by Just *

1911 The solubility of radium emanation in a large number of liquids was determined by *Ramstedt*,[420] who found that the emanation is more soluble in all liquids examined, except glycerol, than in water, it was found to be most readily soluble in carbon bisulphide As regards solubility, therefore, radium emanation is very similar to carbon dioxide †

IV A —*Physical*

Organic compounds of equal molecular symmetry had already been shown by Leidie ‡ to be possessed of equal solubility in a given solvent

1896 Using a racemic mixture and an optically active solvent, *Tolloczko*[7] was able to show that both optically active components dissolved equally

The solubility of supercooled sodium thiosulphate in aqueous alcohol was further studied by *Parmentier*,[2] who found that the solubility varies with the volume of the solvent, that the concentration of the alcohol above the supercooled salt varies, and that a complex condition of equilibrium is established between alcohol, water, and anhydrous salt These results are not in agreement with those previously recorded by Bruner §

From a study of the physical properties of optical isomerides, *Walden*[1] concluded that the *d* and *l* forms of a substance always have the same solubility, density, and melting-point When the racemate has a higher melting-point it has also a smaller solubility

1897 *Kipping and Pope*[19] have discussed the relationship between the solubility of optical isomerides, racemic compounds, pseudo-racemic compounds, and mere mixtures They point out that many misconceptions exist There is no justification for the idea expressed by Walden (loc cit) that the solubility of a mixture of optical antipodes should be twice that of its enantiomorphous constituents No simple relationship is likely to exist in that case or in the case of a racemic compound The opinion was expressed that at present solubility determinations are of no value in distinguishing between racemic compounds and mere mixtures Further evidence was obtained by *Bruner*[28] in support of his contention that the solubility of a supercooled liquid must be greater than that of the solid substance at the same temperature he quoted the cases of hydrocinnamic acid and thymol, and some work done by Alexejeff with salicylic and benzoic acids ‖

1898 The conclusion arrived at by Tolloczko ¶ with regard to the solubility of optical isomerides in an optically active solvent was confirmed by *Goldschmidt and Cooper*,[46] who found no difference between the solubility of *d*- and *l*-carvoximes in *d*-limonene

1901. The theoretical conclusion of Gibbs, that the solubility of a substance depends, to some extent, upon the size of the particles with which the solution is in equilibrium, received experimental proof

* *Zeit phys Chem* , **37, 342** † *Vide* Just, this Section, 1901 ‡ *Vide* Part I , R 90.
§ *Vide* Part I , R. 233. ‖ *Vide* Part I., R. 118. ¶ *Vide* Part II , R 7.

by *Hulett* [96] This observer showed that the solubility of gypsum in water is appreciably greater when the particles do not exceed 0·00003 cm. than when they are as large as 0·0002 cm · the solubility of barium sulphate is affected in the same way This subject was further discussed in a publication by *Marie* [114]

From experiments with alabaster *Bruner and Tolloczko* [102] show that the velocity of dissolution is dependent on the structure, crystalline or granular, of the solid substance used as solute

1902 In the following year *Schick* [132] compared the solubility at 25° and 100° of the red and the yellow forms of mercuric oxide, and found them to be identical *Pomeranz* [151] contributed a mathematical discussion of the relationship between the solubility of the salts of an optically active monobasic acid and of the mixture of the salts of the *d*- and *l*-acids He established a mathematical relationship—$L = l. \sqrt{2}$, in which L represents the solubility of the inactive mixture, and l that of either the *d*- or *l*-salt When the non-dissociated portions were taken into account by the author the equation became

$$L = l \{2(1-a) + \sqrt{2a}\} ;$$

this formula was applied to silver valerate

An influence on solubility, due to the size of the particles, was

1903 detected by *Bottger* [169] when measuring the solubility of sparingly soluble salts The observed effect was small, amounting to about 1 to 2 per cent Further work on this subject was published

1904 by *Hulett*,[195] who, after taking every precaution against errors, affirmed that finely divided gypsum is more soluble than gypsum plates, and that the concentration of the solution saturated with finely powdered gypsum gradually falls, owing to an increase in the size of the particles in contact with the solution This author's criticism of Kohlrausch's * work appears to have been based on a misunderstanding [197] When discussing the solubility of silver chloride with refer-

1905 ence to atomic weight determinations, *Richards and Wells* [236] state that freshly precipitated silver chloride is more soluble than that which has been standing probably this depends upon a change in size of the particles

Holty [235] adversely criticised this conception of small particles having a greater solubility than larger particles, he based his opinion upon experiments made with sucrose dissolving in pyridine

1907 When in the amorphous state the sulphides of the heavy metals were found by *Weigel* [290] to be more soluble in water than when they are in the crystalline state—a result which is not in harmony with Bodländer's formula †

1909 The solubility of a colloid was defined by *Duclaux* [352] as the concentration at the point when no more solvent can be removed from the solution by filtering through collodion under increasing pressure, and by this method he determined the solubility of such different colloids as gelatin and ferric oxide He was able to show that the solubility, thus defined, is related to the size, composition, and electric charge of the molecular clusters which compose the colloid

* *Zeit. phys. Chem.*, **44**, 199. † *Ibid*, **27**, 55.

1910. *Dolezalek*[376] discussed the solubility of gases in liquids from the point of view of his theory of vapour-pressure, and treated the system as a highly concentrated solution of the solvent in the liquefied gas He concluded that under ideal conditions the solubility of a gas should be the same in all indifferent liquids. In a few isolated cases this appears to hold good

A paper by *Wagner*,[377] which appeared in the same year, dealt with the rate of dissolution of salts, the author's conclusion being that no relationship exists between rate of dissolution and solubility

IV. B.—*Chemical*

The conclusions of Carnelley and Thomson * regarding the solubility of isomeric substances were controverted by *Walker and Wood*,[41] who, from an investigation of the solubility of the three isomeric hydroxybenzoic acids in various organic solvents, came to the following conclusions (i) The order of solubility is not the order of fusibility, (ii) the order of solubility is not independent of the solvent used, (iii) the ratio of solubility of the three isomerides in different solvents is not constant

1898.

Herz[40] published data of the solubility in water of chloroform, carbon bisulphide, ligroin, ether, benzene, amylic alcohol, and aniline, and expressed the opinion that no liquid is quite insoluble in water

1902 A publication by *Meusser*[117] showed that chlorates of the metals magnesium, zinc, cobalt, nickel, copper, and cadmium are less soluble than the nitrates, although among the hexahydrates of the chlorates and nitrates no general regularity was apparent At low temperatures the order of solubility of the chlorates follows that of the tension of their normal solutions

Lumsden[118] examined the solubility of calcium salts of a number of fatty acids from formate to pelargonate (nonate) Generally speaking, the results made manifest an increase in solubility of normal chain compounds from formate to propionate, and then a rapidly decreasing solubility as the number of carbon atoms increased The salts of *iso*-acids are generally more soluble than those of the corresponding normal members of the series

Measurements of the solubility of dynamic isomerides engaged the attention of *Lowry*,[178] who proposed this as a useful method of studying the change these substances undergo If at first the more soluble isomeride is present a change into the other form is accompanied by a lowering of the solubility, and *vice versâ*.

1903 *Walker and Fyffe*[157] showed that the solubility curve of barium acetate consists of three distinct portions—namely, that of the anhydrous salt, the mono- and the tri-hydrates

1905 *Dolinski*[222] compared the solubility in water of a number of organic acids, including picric, sulphanilic, naphthionic, and α-naphthylamine-2-sulphonic acid, and of these he found the first two correspond closely.

* *Vide* Part I., R 88, 136

Wolff[249] made an extensive study of the solubility of some simple
1906. and double cerous and ceric salts. Measurements were made by *Lowry*[260] of the solubility of various *di*-halogen derivatives of camphor in alcohol alone and in presence of sodium ethoxide. In the latter case an increased solubility was always observed, but not in the case of β-bromcamphor, nor in cases where both α- and α′-hydrogen atoms were displaced. Increase of solubility was ascribed to the formation of small amounts of the stereoisomeric α′-compound.

Foote and Menge[276] studied the relative solubilities of a number of sparingly soluble barium and calcium salts, and in the same year *Walden*[266] compared the solubilities of tetralkylammonium halides in various organic solvents. He came to the general conclusion that, for any one solvent, the solubility was greater the greater the complexity of the alkyl groups in the positive radicle.

Bottger[267] observed that whilst silver chloride is considerably more soluble at all temperatures than the bromide and the thiocyanate, yet the relative increase of solubility between 0° and 100° is much greater in the case of the two last-mentioned compounds than in the case of the chloride.

The solubility of isomeric organic compounds in water, benzene, and
1907 nitrobenzene was studied by *Rogojawlenski*[316] and others; among the compounds examined were the *o*-, *m*-, and *p*-nitrophenols, nitroanilines, and chlornitrobenzenes; the rule of Carnelley and Thomson,* that the most easily fusible isomeride is the most soluble, was confirmed. The ratio of the solubilities of the isomerides was found to vary with the solvent. Contrary to statements previously published, it was shown by *Jones*[306] that the solubilities of *d*- and *l*-isomerides are identical when dissolved in optically active as well as in inactive solvents.

1908 The solubility of monosodium, monopotassium, and monoammonium urates was compared by *Gudzent*,[346] who made the curious observation that when these substances are shaken with water at any particular temperature the solubility passes through a maximum, and subsequently diminishes. This is *not* due to hydration of the salt nor to any other assignable cause.

IV. C.—*Molecular Weight.*

1897 In the course of his work on the sulphates and selenates of the alkali metals, potassium, rubidium, and cæsium, *Tutton*[18] made determinations of the solubility of these salts, and found that in the two series, selenates and sulphates, the solubility increases as the atomic weight of the metal increases. A comparative study of the solubility at 0° of the hydrated sulphates of magnesium, zinc, and cadmium, carried out by *Mylius and Funk*,[15] showed that the molecular solubility of these salts increases with an increase in the atomic weight of the metal. With the object of finding the existence of some such relationship among the salts of the alkali and alkaline earth metals, these authors[16] measured the solubility of a number of chlorates, chromates,

* *Vide* Part I., R. 136.

nitrates, &c, of these metals. In the main their results were difficult to interpret, owing to many of the salts forming various hydrates, but in the series—lithium chlorate, bromate, and iodate—the molecular solubility was found to decrease in the order given.

An interesting parallelism in the properties of analogous salts was
1900 disclosed by the research of *Funk*.[69] This author compared the solubility of the hydrates of the selenates, molybdates, and tungstates of sodium with the sulphates, and found that all four decahydrates have parallel solubility graphs. The graph for the solubility of the anhydrous selenate is parallel with that of the sulphate; the graphs of the dihydrates of the molybdate and tungstate are also parallel.

Cavalier and Prost[83] compared the behaviour of the trialkyl phosphates, and their results showed that the solubility of these compounds decreases with increasing molecular weight of the alkyl group: whilst the methylic and ethylic esters are miscible with water in all proportions, the butylic ester is very sparingly soluble.

1901 *Meusser*[88] found that the solubility graphs for corresponding hydrates of cobalt and nickel iodates are closely parallel. A study of the solubility of the alums (sixteen in number) enabled *Locke*[112] to deduce an equation expressing their solubility: an equation said to be of general application and to depend upon the atomic weight of the tervalent element and upon that of the univalent metal in the compound. In opposition to these views, mention must be made of the results obtained by *Tarugi and Checchi*.[105] These authors measured the solubility of succinates, cinnamates, benzoates, and salicylates of magnesium, calcium, strontium, and barium, and expressed themselves as unable to deduce any simple relationship between solubility and atomic weight of the metals. Almost at the same time *Rossi*[106] professed to have discovered the existence of a relationship between the solubility of salts of the same series and their molecular weights.

1902. After carefully studying the solubility of a large number of double sulphates of the type $M'_2M''(SO_4)_2 6H_2O$, *Locke*[140] came to the conclusion that the order of solubility is not the order of atomic weight, but that the influence of each metal on the solubility of a salt is specific and manifest in all its compounds.

Rossi had stated that when two salts of the same acid, containing similar metals, are compared, the ratio of their molecular weights is a multiple of the ratio of their solubilities. *Rabe*[147] sought evidence of some such regularity among the salts of thallium but without success: he did, however, observe a simple relationship between the molecular solubility of thallous and potassium salts.

1903 According to *Groschuff*[152] the reverse of the usual order of the alkali metals is obtained when their anhydrous formates are tabulated in the order of increasing solubility, the order then being Li : Na : K.

Tutton[160] found the solubility of ammonium sulphate to be very close to that of rubidium sulphate.

1904 *Stanley*[193] compared the solubility of the formates of the alkaline-earth metals and found that the graphs for anhydrous barium formate and for the dihydrate of strontium formate both have

larger positive temperature coefficients than the graph representing the solubility of calcium formate.* Another instance of an irregular influence being exerted upon the solubility of salts by certain metals was afforded by the observation of *Cantoni and Zachoder*.[209] These authors found that of the tartrates of calcium, strontium, and barium, the strontium salt is most soluble, and the barium salt least soluble.

This work was carried further by the same authors,[241] who in
1905 the following year published solubility determinations for the tartrates of copper, zinc, and lead.

Schroder[248] found that mercuric chloride, bromide, iodide, and cyanide are increasingly soluble in pyridine in the order given above.

1906 In the next year some interesting observations were recorded by *Winkler*[262] on the absorption coefficients in water of a large number of gases at different temperatures. He found that the constant k in his equation † depends upon the number of atoms in the gas molecule, and is proportional to the cube-root of the molecular weight of the gas. The more a gas approximates to the *ideal state* the more nearly constant k becomes.

Experimenting with liquids which separate into layers, *Smirnoff*[283] found that at a given temperature the effect of any one group of metals on the separation of isobutyric acid and water increases as the atomic weight decreases.

The solubility of the malates of the alkaline-earth metals was determined by *Cantoni and Basadonna*[287]; the calcium salt was found to be least soluble and the strontium salt most soluble—a behaviour which is not in harmony with the behaviour of the tartrates and is in direct opposition to that of the succinates of these metals.

It was found by *Walden*[266] that the solubility of the iodides of the alkali metals in furfuraldehyde diminished from lithium to rubidium in the order given; on the other hand, the solubility of the potassium halides in any one solvent is found to increase as the molecular weight of the salt increases.

Trautz and Anschutz[268] found that the solubility of the chlorates, bromates, and iodates of barium decreased in the order above mentioned. The benzoates of strontium, potassium, lead, and zinc were examined by *Pajetta*.[288]

With the object of studying the relationship between molecular weight, atomic weight, and the property of solubility, various other comparisons were made.

1907 *Menschutkin*[308] investigated the solubility of the halides of magnesium, and found that of the three hexahydrates the
1909. chloride is least and the iodide most soluble. *Rimbach and Schubert*[354] contrasted the solubility of the oxalates, tartrates, and iodates of many of the metals of the rare earths.

1910 *Antropoff*[388] studied the solubility in water of the inert gases xenon, krypton, argon, neon, and helium, and found that the absorption coefficient increased as the molecular weight of the solute increased. The solubility of xenon is exceptionally large for a gas which does not combine with the solvent.

* *Vide* Lumsden. Journ. Chem. Soc. 81, 355. † *Vide* Section V. A. 1.

V. A (1).—*Solubility in relation to Temperature.*

From quite early times investigators have given much attention to the study of the nature of the change in solubility attending alterations of temperature. Among the numerous attempts which have been made to find some mathematical equation which would give satisfactory expression to this change, the assumption was made by Le Chatelier that the latent heat of solution of a substance is equal to its latent heat of fusion. This subject was further considered by
1896 *Bancroft*,[9] who was unable to accept Le Chatelier's assumption as it involved the identity of fusion and solubility graphs. He pointed out that in the approximation formulæ for these graphs, which are similar, the factor representing heat of fusion enters into the one and the factor representing heat of dissolution enters into the other; as these factors are not identical, neither can the graphs be identical.

1897 *Bohr*[39] published work on the absorption of gases in liquids at various temperatures and gave the equation $a(T-n)=k$ as representing the solubility of hydrogen, oxygen, nitrogen, carbon monoxide, carbon dioxide, nitric oxide, and ethylene both in water and in the case of several of the gases, in alcohol. In this mathematical expression a = absorption coefficient, T = absolute temperature, and n and k = constants for each gas.

The general 'laws' of solubility enunciated by Schroder * and Le Chatelier † received theoretical support from the thermodynamical
1898 considerations published by *Dahms*[53]. This author also furnished experimental evidence in support of these enunciations, inasmuch as satisfactory agreement was found between the theoretical and practical results obtained with solutions of ethylene bromide in naphthalene, and in certain other cases which he examined.

1899 *Estreicher*[58] found that the solubility curve of helium in water exhibits a minimum at 25°, being similar in this respect to hydrogen. It was suggested that this peculiarity is connected in some way with the difficulty with which these gases are liquefied.

Franklin and Krauss[62] measured the solubility of a large number of elements and compounds in liquid ammonia. They found that, whereas some substances are apparently insoluble in that solvent at its boiling-point, when under pressure at 25° C. they are readily soluble.

1900 A somewhat remarkable contribution to the study of solubility phenomena was made by *Mylius, Funk*,[67] *and others*,[84] who measured the solubility of chromates, molybdates, tungstates, and selenates of sodium and of calcium, and contrasted the solubility-temperature graphs they obtained. The hydrates of calcium chromate[69] were found to give an extraordinary set of solubility graphs, which were traced[68] for each of the following salts from 0° to 100° C.—$CaCrO_4,H_2O$, $CaCrO_4,\frac{1}{2}H_2O$; $CaCrO_4$. In each case the solubility was found to decrease as the temperature was raised, and the solubility graphs were found not to cut one another but to be nearly parallel—results which are not in harmony with current ideas of stable and labile hydrates.

* *Vide* Part I., R. 202. † *Vide* Part I., R. 221.

Cavalier and Prost[83] examined the solubility of some metallic alkyl phosphates, and found the lead salts—$(PO_4R_2)_2Pb$—to be more soluble in hot than in cold water, whilst the barium salts PO_4RBa decrease * in solubility as the temperature is raised.

1901 Observations somewhat similar to these were made by *Meusser*,[88] who worked with the iodates of cobalt and nickel and found the solubility of the di- and tetra-hydrates increase with rising temperature, whereas under similar circumstances the solubility of the anhydrous salts diminishes.

In the same year the relationship between temperature and solubility of barium oxalate was studied by *Groschuff*,[89] and *Winkler*[87] calculated the absorption coefficients of air, nitric oxide, carbon monoxide, methane, and ethane at temperatures ranging from 0° to 100°. The values found by this investigator were slightly different from those previously obtained by Bunsen. The solubilities of gaseous oxygen, methane, and ethane in methylic alcohol and acetone were found by *Levi*[107] to decrease regularly with rise of temperature, in accordance with the general rule of gaseous absorption.

1902 *Lumsden*[118] found that with rise of temperature the solubility curves of hydrated calcium salts of fatty acids first fall to a minimum and then steadily rise again. The anhydrous formate, however, gives a continuous rising curve.

A careful study of the solubility of natural gypsum in highly purified water was conducted by *Hulett and Allen*.[141] *Meusser*[117] determined the transition points of various hydrated chlorates of manganese, zinc, cobalt, nickel, &c. from solubility graphs, and the solubility data for ammonium nitrate in water between 12° and 40° were revised by *Muller and Kaufmann*.[133]

1903 According to *Euler*[153] the solubility of silver oxide and silver chloride in aqueous methylamine and ethylamine varies but little with change of temperature. In the case of anthracene, anthraquinone, and quinol dissolved in liquid sulphur dioxide the temperature influence was found to be large. *Centnerszwer and Teletoff*[182] state that these substances are quite sparingly soluble at ordinary temperatures, but the solubility increases rapidly as the temperature is raised.

Study was made of the solubility and transition points of lithium nitrate and its hydrates by *Donnan and Burt*,[158] and the solubility curve of sodium tetraborate was traced by *Horn and Wagener*.[174] These latter authors found that there was a marked change of direction in the neighbourhood of 60° to 62° on the curve, thus confirming the observations of Lescœur, who had found previously, from vapour tension measurements, that 60° was the temperature of transition from the *deca*- to the *penta*-hydrate.

Lichty[175] determined the solubilities of the halide salts of lead at temperatures ranging from 0° to 100° C. He found that the iodide is least soluble and the bromide the most soluble at 100°, at 0° the chloride is the most soluble. *Cassuto*[181] experimented with hydrogen, oxygen, nitrogen, and carbon monoxide and found the solubility in water to decrease rapidly as the temperature rises.

* An exception being the salt of the ethyl compound which has a maximum solubility at 40° C.

1904. The solubility-temperature curves of the hydrates of nickel sulphate were determined by *Steele and Johnson*,[190] who deduced the transition points between the two hexahydrates—blue and green—and the transition points between the hexa- and hepta-hydrates

Stanley[193] compared the solubility curves of hydrates of the formates of calcium, strontium, and barium, and showed the difference between their temperature coefficients

The stability relationship of five different hydrates of cerous sulphate was investigated by *Koppel*[217] by means of solubility graphs *Hudson*,[207] working with the three forms of milk-sugar, came to the conclusion that hydrates change but little with change of temperature, the change being in the direction of increased hydration with rise of temperature * In a mathematical paper by *Richardson*[211] an equation was deduced which expressed the variation of solubility with change of temperature when a gas dissolves and at the same time dissociates in a liquid The equation put forward is dependent upon the heats of dissolution of the dissociated and of the undissociated gas

Later on, in the same year, *Kohlrausch*[203] published a compilation of results of solubility determinations of sparingly soluble silver salts, which were arrived at from electrical conductivity measurements He complained that knowledge of the influence of temperature on these phenomena was still very incomplete

The solubility of anthracene, anthraquinone, and quinol in liquid sulphur dioxide at different temperatures further engaged the attention of *Centnerszwer and Teletoff*[218] From calculations based upon the phase rule these authors concluded that the 'mean solubility' † of a sparingly volatile substance is not of constant magnitude at any particular temperature

Cantoni and Zachoder[209] determined the solubility of tartrates of barium (anhydrous), strontium ($+3H_2O$), and calcium ($+4H_2O$), and found a positive temperature coefficient in each case *Bresler*[196] plotted solubility-temperature graphs for β *l*-asparagine and β *l*-aspartic acid from 0° to 100° C , and derived an equation therefrom expressing the relationship between solubility and temperature for those substances

The solubilities of a large number of salts over a wide range of temperature were determined by the *Earl of Berkeley*[213] among the salts used were the chlorides, sulphates, and nitrates of sodium, potassium, rubidium, cæsium, and thallium

1905 According to *Aten*[233] the solubility curves of mercuric chloride in acetone and in ethylic acetate are nearly parallel to the temperature axis In the case of sulphur dissolving in aqueous solutions of sodium sulphide similar observations were made by *Kuster and Heberlein*,[211] who found that between 0° and 50° the solubility was almost independent of the temperature

The solubility of sulphur in benzyl chloride was determined by

* See also *Hudson* and *Brown* J Amer Chem Soc [1908], **30**, 960

† By the 'mean solubility' is meant $(S+O)$ $(l+\lambda)$, in which S and O denote respectively the quantities of substance dissolved in liquid SO_2 of weight l and vapour of weight λ

Bogwski [238] over a wide range of temperature *Cantoni and Zachoder* [241] continued their work on the solubility-temperature graphs of metallic tartrates, and data for the solubility of phosphorus in ethylic ether and benzene at different temperatures were published by *Christomanos* [250]

1906. *Winkler* [262] made a careful study of the effect of temperature changes on the absorption coefficients of gases in water He deduced the following equation * to express the relationship between temperature, internal friction of solvent, and molecular weight of gas If β and β_1 represent the absorption coefficient at two temperatures, μ and μ_1 the corresponding values for the internal friction of water, and m the molecular weight of the gas, K being a constant, then

$$\frac{\beta - \beta_1}{\beta} = \frac{\mu - \mu_1}{\mu} \cdot \frac{\sqrt[3]{m}}{K}$$

(Compare Sections III A and IV B.)

Rex [263] studied the absorption coefficients of halogenated hydrocarbons from the same point of view, and found that the behaviour of these substances was similar to that of gases; but the constant K was found to increase with the molecular weight of the gas

Solubility measurements were made with the malates of the alkaline earth metals at various temperatures by *Cantoni and Basadonna* [287]

Pajetta [288] observed that whereas the benzoates of strontium, potassium, and lead have small positive temperature coefficients of solubility, in the case of the zinc salt the temperature coefficient is negative

Work of a similar nature carried out by *Walden* [266] showed that tetramethyl ammonium iodide has a positive temperature-solubility coefficient in twenty-three solvents investigated, whereas potassium iodide has a negative coefficient in all solvents except water, glycol, and methylic and ethylic alcohols

The solubilities between 20° and 100° of the chloride, bromide, and thiocyanate of silver were determined by *Bottger*, [267] the chloride in particular being found to be appreciably soluble at 100° C In the

1907. following year *Menschutkin* [308] traced the solubility-temperature curves of the hydrates of magnesium bromide and iodide †

In continuation of a previous publication, ‡ the available data for the solubility of a large number of sparingly soluble salts at different

1908. temperatures were collected together by *Kohlrausch* [329] The temperature-solubility graph for lime in water was published by *Moody and Leyson* [323]

The solubility of silver iodide in aqueous ammonia was observed by *Baubigny* [325] to increase appreciably with rise of temperature

1910 By means of the electrical conductivity method of measuring solubility, *Melcher* [384] determined the solubility of silver chloride and of the sulphates of barium and calcium in water at relatively high temperatures—namely, from 18° to 218° C The

* *Vide* Part I., R. 190.
† *Vide* Étard, Part I., R. 214, and Mylius and Funk, Part II., R. 16.
‡ *Vide* this Section, 1904.

results obtained were compared with those previously recorded by Bottger and Kohlrausch In the case of calcium sulphate the solubility of the three forms, gypsum, anhydrite, and soluble anhydrite, was ascertained

Von Antropoff[388] studied the relationship between solubility and temperature in the cases of the inert gases, xenon, krypton, argon, neon, and helium *Centnerszwer*[378] carried out similar work with potassium iodide and other salts when dissolved in methylic alcohol at temperatures up to the critical temperature of the solvent The main conclusion of this latter work was the detection of a point of maximum solubility at 196° C, from which temperature the solubility decreased to the critical temperature, 266° C

Tyrer[370] investigated the solubility of sodium iodide in ethylic and methylic alcohols from ordinary room temperature up to about 300° C The solubility-temperature graph was found to rise at first, then to fall as the critical temperature is approached, and above that point the solubility is dependent upon the concentration of the solvent and decreases with rising temperature

1911. Interesting observations on the solubility of gaseous hydrogen in the metals, iron, copper, and nickel, were made by *Sieverts*[402] He determined the solubility of this gas in these metals at temperatures from 400° to 1,600° C, and found a gradual increase in the amount of hydrogen dissolved as the temperature was raised, and a sudden increased solubility when the metals melted

Nasini and Ageno[421] determined the solubility of *ortho*boric acid at various temperatures, and could not detect a break in the continuity of the graph at 107-108°, the temperature at which that substance changes to *meta*boric acid

Brichaux[422] carried out an investigation of the laws relating to vapour pressure and temperature of solutions saturated with ammonia He concluded that the ammonia content of a solution is determined by the 'differential temperature'—*i e*, the difference between the temperature of an ammoniacal solution and the temperature at which water boils at the same pressure The figures which he gave indicated that this relationship holds with considerable accuracy

V A (ii) —*Solubility in relation to Heat of Dissolution*

When a substance undergoes a change of state, whether it be evaporation, liquefaction, crystallisation, dissolution, or some other manifestation of change in the state of aggregation, there is always a concomitant change in the energy content of the substances In so far as the study of solubility is concerned, very little regard has been taken of the energy changes which occur, and scarcely any attempt has been made to correlate energy content with powers to dissolve

It was recorded in Part I of this Report that van't Hoff (1) and van Laar (2) deduced mathematical equations showing the relationship which exists between heat of dissolution, dissociation constant, and solubility of binary electrolytes

$$(1) \qquad d \log c/dt = Q/2(1+a)T^2$$
$$(2) \qquad d \log c/dt = Q(2-a)/4T^2$$

The accuracy of these expressions was discussed in a communication
1898. by *Goldschmidt and Maarseveen.*[43] These authors determined all three quantities experimentally for some sparingly soluble salts—silver salts of fatty acids—and found that the observed heat of dissolution lay between the values calculated from the above two
1900 equations Not long afterwards *van Laar*[76] published a paper dealing mathematically with this subject, he developed a formula connecting heat of dissolution and solubility, and showed by experiments the nature of the difference between his and the formula proposed by Van't Hoff

1901. *Campetti*[111] derived a somewhat complex equation which represented the relationship between solubility and heat of dissolution, which was based upon van't Hoff's study of the influence of temperature on chemical equilibrium The equation is only valid for those cases in which the substance is not dissociated when dissolved He applied it to the cases of carbamide and mannitol with success

Holsboer[108] pointed out that if the solubility of a compound increases with rise of temperature, the theoretical heat of dissolution—the heat of dissolution in a saturated solution—must be negative and *vice versâ* This being so, where the solubility curve of a substance passes through a minimum the heat of dissolution should be zero This he found experimentally was true of cadmium sulphate $CdSO_4$, $8/3H_2O$ Holsboer also argued that if the thermal capacity of a solution is an additive property, heat of dissolution should be independent of temperature

1903. Van't Hoff's equation connecting heat of dissolution and change of solubility with change of temperature in the case of electrolytes was tested experimentally by *Noyes and Sammet*[163] In the case of *o*-nitrobenzoic acid agreement was not good, but in that of potassium perchlorate the agreement was sufficiently close to be regarded as evidence that conductivity is a correct measure of dissociation

1904 The relationship between solubility and heat of dissolution in the case of gaseous absorption was theoretically discussed by *Richardson*[214] A mathematical equation was deduced by him connecting the variations of solubility of a gas dissolving in a liquid and at the same time undergoing dissociation, with the difference between the heats of dissolution of the dissociated and non-dissociated gas

V B.—*Influence of Pressure*

1896 *v Stackelberg*[5] investigated the influence of pressure on solubility He experimentally determined the solubility of sodium chloride, of ammonium chloride, and of alum at 18° C. under different pressures up to 500 atmospheres, and compared the results so obtained with those calculated from a thermodynamic equation which he had evolved, and which was independent of the temperature coefficient Approximate agreement was observed between the calculated and the experimental results, although in some cases there were large divergencies The solubilities of sodium chloride and of alum were

found to be increased by pressure, whereas under similarly changed conditions the solubility of ammonium chloride was decreased

The non-obedience to Henry's law of solutions of carbon dioxide in water was attributed by *Jakowkin*[4] to the existence of double molecules of solute—$(CO_2)_2$—when in the gaseous state, and of only simple molecules—CO_2—when dissolved in water *

1897 From the observations of *Spezia*[32] it would again appear that increase of pressure does not always occasion an increased solubility In the case of quartz this author could detect no change in weight of the solute after it had been kept in water at 27° for several months under a pressure of some 1,800 atmospheres

1900 From the fact that solutions of ammonia in aqueous salt solutions do not obey the Henry-Dalton rule of partial pressure, *Konowalow*[79] came to the conclusion that the ammonia enters into combination with the salt in solution

Increase of pressure was found by *Van der Lee*[73] to raise the critical temperature of complete miscibility of phenol and water, a result which is quite in harmony with Van der Waals' theorem when applied to solutions †

1903 *Cassuto*[181] gave results of measurements of solubility of oxygen, hydrogen, nitrogen, and carbon monoxide in water when under pressures varying from 1 to 10 atmospheres He showed that between 19 5° and 23 4° C Ostwald's coefficient of solubility ‡ for oxygen and nitrogen decreases more rapidly than the pressure increases At pressures near to the atmospheric pressure the solubility coefficients are nearly constant for constant temperatures

1909 *Cohen and Sinnige*[255, 356] studied the influence of pressure upon the solubility in water of the salts $CdSO_4,8/3H_2O$ and $ZnSO_4,7H_2O$, the range of pressure being from 1 to 1,000 atmospheres An increased pressure was found to produce a marked increase of solubility with the cadmium salt but quite a slight decrease in that of the zinc salt

With regard to the influence of pressure upon the mutual solubility of a pair of liquids, work similar to that recorded by Van der Lee § was carried out by *Timmermans*,[365] who showed that in general a pair of liquids may be made to pass through all stages of miscibility by varying the external pressure It is thus possible to pass continuously from dilute to concentrated solutions by simply varying the pressure On this basis the author proposed to elaborate a theorem by applying to concentrated solutions conceptions similar to those of Van der Waals

1910. Continuing his work on the influence of pressure upon solubility, *Cohen*,[398] with Inouye and Euwen, found that the solubility, both of sodium chloride and of mannitol, steadily increases as the pressure is increased from 1 to 1,500 atmospheres, the total solubility-increase being about 5 per cent

* See also Section VI. † *Vide* Part I, R 181.

‡ Ostwald's coefficient of solubility $\lambda = \frac{V}{v}$, in which v=volume of liquid which dissolves volume V of gas at known temperature and pressure.

§ *Vide* this Section 1900

Very interesting results were obtained by studying the effect produced by pressure on the solubility of gases in liquids when in the presence of some other substance *Drucker and Moles* [382] worked with hydrogen and nitrogen, and found that when these gases are dissolved in mixtures of water and *iso*-butyric acid, Henry's rule is obeyed even at the critical solution point of the two liquids *Findlay and Creighton* [369] experimented with fine suspensions of silicic acid and ferric hydroxide in water, and found the solubility of gases in these solvents was affected by pressure in those cases in which the presence of the colloid altered the solubility of the gas

Sieverts and Krumbhaar [368] observed that when gases dissolve in metals—for example, sulphur dioxide dissolving in copper or oxygen in alloys of gold and silver—the solubility is proportional to the square
1911 root of the pressure In a subsequent publication [402] this was also found to be true of solutions of hydrogen in copper, iron, and nickel, except at pressures below 100 mm, when no such relationship was observed

V C —*Influence of other Substances*

(1) *Non-electrolytes influenced by Non-electrolytes*

1896 *Tolloczko* [6] made numerous experiments with the object of studying the solubility of ethylic ether in water as affected by the addition of various organic substances The results he obtained seemed to be in support of Nernst's theorem * Results which were
1897 not in harmony with the requirements of this theorem were recorded soon afterwards by *Schiff*,[27] who observed that certain organic substances—phloretin for example—are much more soluble in ether which is saturated with water than in either water or ether alone † In the same year *Benedict* [35] published observations of a similar phenomenon with camphor and with naphthalene, and, although *Talmadge* [37] was unable to confirm completely these results with naphthalene, his work showed that the vapour pressure of a solute does vary with different solvents In the case of camphor the values with ether and acetone are more than double the real vapour pressure, with methylic alcohol the calculated vapour pressures are a little above the normal and with ethylic alcohol only about one-half those found experimentally

1900 *Braun* [74] determined the absorption coefficient for nitrogen and for hydrogen in aqueous solutions of carbamide and propionic acid at various temperatures between 5° and 25° C He found that the solubility relationship could be expressed by the equation $C_1/C_2=1$, in which C_1 = molecular concentration of the gas in pure water, and C_2 = molecular concentration in the solution of one of the so-called indifferent substances at the same temperature and partial pressure

In so far as the solubility of *p*-nitrophenol in benzene, *m*-xylene, and chloroform is increased by the addition of small quantities of
1901. water, the observations made by *Lotmar* [65] were confirmed by *Meyer* [115] It was, moreover, further established that the addi-

* *Vide* Part I., R. 144.

† This author's original notice of these facts is to be found in *Ann. d. Chem.* [1885], **229**, 371.

tion of other non-electrolytes such, for example, as chloroform, nitrobenzene, and toluene instead of water also caused an increased solubility of p-nitrophenol in the medium benzene Of these added substances, alcohols, esters, and ketones were found to exhibit the greatest effect, nitroparaffins the least effect, and hydrocarbons, also chloroform, did not change the solubility of p-nitrobenzene from that found in pure benzene.

The solubility of carbon monoxide in binary organic mixtures was investigated by *Skirrow*[128]

Jahn's * empirical law correlating solubility of gases and the concentration of electrolytes present in the aqueous solvent was found by *Levi*[107] to hold also for methylic alcohol solutions of potassium iodide and carbamide

In a communication upon the subject of the influence exerted by foreign substances on the solubility of phenylthiocarbamide and of boric
1903. acid in water, *Bogdan*[176] published results showing that the solubility of these solutes is increased by the presence of non-electrolytes such as carbamide, sucrose, acetone, ethylic, and propylic alcohol

The work recorded by Schiff (1897) was carried further by
1905 *Stromholm*,[242] and similar results were obtained It was found that small quantities of water greatly increase the solubility in ether of a large number of organic compounds More especially was this found to be true with hydroxyl compounds, carboxylic acids, and phenols, although other compounds were also found to dissolve more readily in ether containing small quantities of water than when that solvent was perfectly dry

Morse and Fraser † having shown good reason for comparing weight-normal rather than volume-normal solutions, *Philip*[307] recalculated from available data the solubility of gases in aqueous solutions of non-electrolytes—for example, hydrogen in chloral hydrate solutions He found that on this basis of comparison approximately constant solubility values are obtained for hydrogen dissolved in water, although the proportion of chloral hydrate present may vary considerably

1908 The work of *Kofler*[339] dealing with the influence of other substances on the solubility of radium emanation is of interest, although its significance cannot well be appreciated until more is known of the nature of the emanation In water-alcohol mixtures the emanation is increasingly soluble as the proportion of alcohol is increased, cane sugar, however, decreases its solubility in water

An unusually pronounced instance of change in the solvent power of a liquid when a second liquid is added thereto is to be found in the work of *Galeotti and Giampalmo*[340] These authors experimented with zein, a protein obtained from maize, and found it to be insoluble in all pure solvents although readily soluble in mixtures of alcohol and water The maximum solubility was observed to be in 60 per cent alcohol They also studied the variations of solubility of this protein in mixtures of water, alcohol, and acetone, and also in mixtures of chloroform and alcohol

* *Vide* Part I, R 240
† *Amer Chem J* [1905] **34** 1 [1906] **36** 1 and 39

1909. *Fuhner*[349] observed that the solubilities of ether and phenol are mutually diminished when these substances are dissolved simultaneously in water

1910. From the experiments recorded by *Findlay and Creighton*[369] it appears that the solubility of gases in water may be either increased or diminished by the presence of fine colloidal suspensions Thus charcoal and silica increase the solubility of carbon dioxide and nitrous oxide, whilst a number of organic colloids such as starch and albumen, diminish the solubility of these gases.

The mutual solubility influence of ethylic and amylic alcohols in water was investigated by *Fontein*[379] From his results he was able to construct a complete equilibrium diagram for the system referred to

With the object of ascertaining how far the solubility of a substance varies with the concentration of the solvent, *Tyrer*[372] determined the solubility of anthraquinone in benzene and in chloroform and then diluted the solvent with varying quantities of hexane—in which the solute is insoluble—and again determined the solubility From the results obtained, however, no general conclusions could be drawn *

Drucker and *Moles*[382] made measurements of the solubility of hydrogen and nitrogen in mixtures of glycerol and water, and contrasted the solubility graphs for various concentrations of solvent with other physical properties of the binary system glycerol + water

V. C —*Influence of Other Substances*

(ii) *Non-electrolytes influenced by Electrolytes, and Electrolytes influenced by Non-electrolytes*

Soon after the publication of *Steiner's* † research showing cane sugar to be particularly active in decreasing the solubility of hydrogen in

1896 water, *Weisberg*[14] found that calcium sulphite is twice as soluble in a 10 per cent sucrose solution as it is in pure water The study of the change of solubility occasioned by the presence of organic substances in the solvent was further studied by *Bathrick*,[10] who experimented with organic salts and aqueous solutions of salts This author was able to show by his experiments that Bancroft's equation $(x+A)\ y^n = C$, ‡ expressing the solubility of salts in alcohol was valid also in the case of salts dissolving in aqueous alcohol and acetone This work on the precipitation of salts from aqueous solutions of

1897. alcohol and acetone was continued by *Taylor*[38] who substantiated the results previously recorded

Bodtker[24] found that whereas anhydrous oxalic acid is more soluble in ether than the hydrated acid, the hydrated forms of copper and cobalt chloride are more soluble in ether than are the anhydrous salts Further, these hydrated salts are more soluble in concentrated than in slightly aqueous alcohol This work should be considered in connection with *Schiff's* research on aqueous ethereal solutions §

A brief review of the recorded work dealing with the subject of the absorption of gases by aqueous solutions of electrolytes was

* *Vide* Section VII
† *Vide* Part I. R. 219
‡ *Vide* footnote, Section V. A (i)
§ *Vide* Section V. C. (i).

published by *Roth* [29] He submitted the empirical relationship * expressed by

$$\frac{a - a^1}{M^{2/3}} = k$$

to exhaustive tests and found it to be valid

1899 *Euler* [60] obtained results similar to those recorded by Roth in that part of his work which dealt with the solubility of ethylic acetate in salt solutions Thus, the equivalent diminution of solubility was found to become greater with dilution of the salt solution, and, if the various salts be arranged according to their values for equivalent diminution of solubility, the order of arrangement is the same whether the dissolved substance be hydrogen, nitrous oxide, or ethylic acetate The investigation of the absorption of gases by

1900 aqueous solutions was carried a step further by *Braun*,[74] who studied the solubility of nitrogen and hydrogen in aqueous solutions of non-electrolytes and electrolytes at temperatures ranging from 5° to 25° C In the case of electrolytes, the empirical relationship formulated by Jahn was found to hold In the case of non-electrolytes, if C_1 represents the molecular concentration of gas in pure water and C_2 that in the solution of an indifferent substance, the equation $C_1/C_2=1$ was found to express the relationship which obtains

An extensive investigation of the solubility of various salts of calcium, iron, and copper in sucrose solutions of different strength and at different temperatures was carried out by *Stolle* [81] The series of results recorded are of great complexity and very difficult to interpret

Rothmund [72] brought forward further evidence to disprove the idea that salts in solution do not affect the solubility in water of non-electrolytes In this publication the solubility of phenylthiocarbamide in water is shown to be diminished considerably by sulphates, carbonates, nitrates, and other salts, the relative order of the salts as regards this effect being the same as has been observed when carbon dioxide, hydrogen, nitrous oxide, and ethylic acetate were the solutes employed Work of a somewhat similar nature was published by

1901 *Dawson and McCrae*,[91] who found that the distribution of ammonia between water and chloroform is changed to quite a considerable degree by the presence of carbamide and of sucrose In the same year *Mellor* [90] published a research on the solubility of chlorine in aqueous solutions of hydrogen chloride When graphically represented, his results exhibited a minimum solubility at about 2 per cent HCl, a fact which the author discussed from the point of view of the products formed when chlorine is dissolved in aqueous solutions of hydrogen chloride

1902 In a paper in which the acid nature of acetylene is discussed, *Billitzer* [125] showed that sodium sulphate lowers the solubility of ethylene and acetylene to about the same extent, but, alkalies—NaOH, KOH, and NH_4OH—lower the solubility of ethylene more than that of acetylene *Lumière and others* [150] found the

* *Vide* Jahn, Part I R 240

solubilities of sodium sulphate and trioxymethylene are mutually increased when these substances are dissolved together in water; in neither case, however, is the increase directly proportional to the concentration of the solvent. *Dawson and Gawler*[121] observed a similar phenomenon with iodine and potassium iodide when dissolved in nitrobenzene. In this case, the largely increased solubility of these two substances is attributed to the union of the solutes with the formation of polyiodides in solution.

The solubility of anhydrous sodium acetate in alcohol of different strengths was studied by *Schiavon*.[149]

The requirements of the electrolytic dissociation theory are such that, in dilute solutions, the presence of electrolytes in the solvent water should be without effect upon the solubility of non-electrolytes.

1903 When submitted to practical test by *Biltz*,[162] this was not found to be true. Biltz found the solubility of phenylthiourea to be lowered materially by various inorganic salts, and, generally speaking, the salts of lower molecular weight were found to produce a greater lowering effect. The nitrates of rubidium, cæsium, and ammonium cause an increase in the solubility. 'A study of the influence of foreign substances on the solubility of phenylthiocarbamide in water' which was carried out by *Bogdan*[176] furnished additional evidence contradictory to the theory above referred to. The solubility of phenylthiocarbamide in water is diminished by the presence of electrolytes such as sodium and potassium nitrate.

According to *Bougault*,[177] picric acid is more soluble in wet than in dry ether. The solution in the latter is colourless, but in wet ether it is yellow.

Euler[153] found the solubility of silver oxide and silver chloride in aqueous ethylamine and methylamine solutions to be approximately proportional to the concentration of the amine.*

Goldschmidt[186] claimed to be the first to observe a lowering of the solubility of an electrolyte being occasioned by a non-electrolyte. His observations were made with ammonia and he found the absorption coefficient to be lowered by the presence of carbamide in the water.

An important contribution to the study of solubility influence was made by *McLauchlan*.[165] This author examined the influence of salts upon the solubility of hydrogen sulphide and bromine in water and made observations of the behaviour of a large number of salts from this point of view. The sulphates, chlorides, and nitrates of sodium, potassium, and ammonium were all found to raise the partial pressure of hydrogen sulphide. Bromine was found to be more soluble in salt solutions than in pure water, except in solutions of potassium nitrate, sodium nitrate, potassium sulphate and sodium sulphate, all these substances, as well as ammonium sulphate, were found to diminish the solubility of iodine.

1904 It was found by *Clowes and Briggs*[192] that atmospheric oxygen is less soluble in sea-water than in pure water, the sodium chloride diminishing its solubility.

* The results differ widely from those found by Wuth, *vide* 'Ber.,' 35. 2415.

Dawson and Goodson[191] continued their work on the solubility of iodine in salt solutions and published further results showing that the iodides of sodium, rubidium, cæsium, lithium, strontium, barium, and tetramethylammonium all behave like potassium iodide in so far as they increase the solubility of iodine in nitrobenzene

Euler[210] studied the lowering of solubility of aniline in water occasioned by certain chlorides and by sodium and potassium hydroxide Later in the same year[211] he compared the parallel effect of different electrolytes in lowering the solubility of hydrogen, nitrous oxide, and ethylic acetate in water He concluded that the equivalent lowering of solubility is an additive property of the two dissolved substances and he showed that if l_0 and l represent the solubilities in water and solution respectively and c the concentration of salt, then,

$$\frac{l_0 - l}{C^{3/4}} = \text{a constant.}$$

In a later communication,[201] in which he included a general summary of his own results and those of many other workers showing the influence of electrolytes on the solubility of non-electrolytes, this author suggested the expression $\frac{l}{n^y} \cdot \frac{l_0 - l}{l_0}$ as being independent of the concentration *

The solubility of gases in aqueous solutions of electrolytes has also been studied by *Knopp*[198] and by *Geffcken*[200] The latter connected the influence of electrolytes on the solubility of gases with their effect on the internal pressure of the solution

The interesting observation was made by *Herz and Knoch*[216] that potassium permanganate and sodium chloride are more soluble in water containing acetone than in pure water, although these substances by themselves are almost insoluble in pure acetone

1905 Continuing this work with potassium bromide and ammonium chloride dissolved in aqueous acetone, *these authors*[251] observed a behaviour similar to that previously found with sodium chloride, and the relationship $\frac{W}{\sqrt[3]{S}}$ = constant, suggested by Bodlander, was found to be true in these cases With mercuric iodide dissolved in aqueous alcohol, such relationship was not found to be true Experiments were made also with various salts dissolved in aqueous solutions of glycerol and, in a subsequent publication, *these authors*[252] recorded their observations of an increased solubility of calcium hydrate being occasioned by increasing the amount of glycerol present in the solvent The solubility relationship, in the case of calcium hydrate and aqueous glycerol, they expressed in the form of a mathematical equation

Fleckenstein[243] observed that whilst the presence of ethylic alcohol diminishes the solubility of ammonium nitrate in water the addition of methylic alcohol to the water increases the solubility of that salt He

*** In this expression l=solub in aqueous solution, l_0= solub in water, n=grammes of substance per litre of aqueous solution; y=degree of dissociation of substance.**

also found, within certain limits of temperature and concentration of alcohol, that separation into layers may take place, but this only occurs in the presence of solid salt.

The solubility of sulphur in sodium sulphide solutions depends to a large degree upon the concentration of the latter To judge from the evidence recorded by *Kuster and Heberlein*,[244] the equilibrium conditions involved are very complex.

The work of *Hoffman and Langbeck*[230] shows that the influence of added electrolytes depends largely upon the temperature thus, dextrose has no effect at 25°, but at 45° it increases the solubility of benzoic acid and it causes a decreased solubility of *o*-nitro-benzoic acid Although there are some exceptions, in general, non-electrolytes were found to occasion an increased solubility of benzoic acid and some of its derivatives, whereas, electrolytes at first raise and then lower the solubility of these substances

Rogowicz[239] found that barium sulphite is less soluble in sugar solution than in pure water and, in the same year, *Worley*[227] measured the solubility of bromine in aqueous solutions of potassium bromide

1906 The interesting effect caused by the addition of lithium sulphate to the system alcohol-water-ammonium sulphate, which forms two liquid layers, was studied by *Schreinemakers and Bornwater*[281] At first the addition of lithium sulphate facilitates the separation of alcohol and water into two layers; then, the reverse takes place and the two layers become more and more similar in composition as the addition of the sulphate is continued With the object of throwing light upon this phenomenon *Schreinemakers and v Dorp*[280] investigated the solubility behaviour of lithium sulphate in aqueous alcohol of varying concentration They found that in 80 per cent alcohol this salt is practically insoluble

Riedel[269] found that bases, such as barium hydroxide, have a greater lowering effect upon the solubility of aniline in water than have salts, the effect increasing with the strength of the base employed According to *Lowry*,[260] whether sodium ethylate increases the solubility in alcohol of various dihalogen camphors depends upon the position occupied by the substituting halogen atom in the molecule

The influence of salts upon the solubility in water of such substances as serum globulin is of wide interest *Galeotti*[286] found that with increasing concentration of magnesium sulphate, the solubility of the globulin increases, but when the concentration of magnesium sulphate approaches the point of saturation, the globulin is precipitated

Hudson[288A] contributed a paper dealing with the formation of hydrates in solution which has bearing on solubility influences The separation of water and *iso*-butyric acid into two layers by the addition of soluble salts was studied by *Smirnoff*[283] He found the effect of any one group of metals on the separation of acid and water increased as the atomic weight decreased; similar observations being made with varying acid radicles A further communication on this subject ap-

1907 peared in the following year[317A] The work of *Armstrong*,[305] *Eyre and others* on the graduated displacement of salts from solution by various precipitants furnished interesting results. They

contrasted the behaviour of alcohol as a representative electrolyte and weak dehydrant with that of hydrogen chloride as a representative electrolyte and moderately powerful dehydrant, the main point brought out being the similarity in the behaviour of these two precipitants. These results are not in harmony with the views expressed by Nernst * and Noyes † and are in opposition to Levin's ‡ contention that non-electrolytes exert no influence upon the solubility of other substances: a statement which was also adversely criticised by *Philip* [307A]

The solubility of the halides and cyanides of mercury in mixtures of water and respectively methylic and ethylic alcohols and ethylic acetate was studied by *Herz and Anders* [309] The solubility results found experimentally were always less than the solubility values calculated on the assumption that each constituent of the mixture independently exerts its own solvent power Similar results [311] were observed with the halides of potassium and, in the case of these salts in mixtures of water and methylic alcohol, the greatest difference from the values calculated on the above assumption was observed to coincide with the maximum viscosity of the mixed solvents Those communications prompted *Duleski* [310] to publish his measurements of the solubility of mercuric chloride in binary organic solvents § The observed values were not found to be in agreement with those which he calculated from a knowledge of the solvent powers of the constituents of the mixtures employed, and he was unable to arrive at any general conclusions from this work

Smirnoff [317] published tables and curves showing the effect of various salts on the separation of solutions into two layers and also the solubility of various fractions of butyric acid in water at various temperatures

Following the lead given by Morse and Fraser ‖ and by Caldwell,¶ available data relating to the absorption of gases by aqueous solutions of salts were collected by *Philip*,[307] who recalculated the solubilities on the basis of a weight-normal comparison Making the assumption that the lowering of the solvent power of water is due to the hydration of the added electrolyte, this author calculated the hydration values of the added substances

The solubility of acetanilide in mixtures of water and alcohol was determined by *Seidell* [301]

Results contradictory to those recorded by *Hufner* [293] are to be
1908. found in the research of *Usher* [328] on the influence exerted by the sulphates of nickel and cobalt and of manganese chloride upon the solubility of nitric oxide in water This work revealed the fact that these salts, unlike ferrous sulphate, diminish the solubility of the gas in water

The effect of various colloids upon the solubility of carbon dioxide in water formed the subject of an investigation by *Findlay* [341] The

* Part I R 144. † Part I. R 164 ‡ *Vide* Section VII.

§ This work was carried out in 1898, and use was made of the results obtained by Timofejeff (*vide* Part I R 171)

‖ *Amer. Chem. J.* 1905, **34**, 1, 1906, **36**, 1 and 39

¶ *Roy. Soc. Proc.* 1906, A **78**, 272.

results of this work, although of great interest, do not admit of any general conclusion being drawn

Schroder [342] measured the solubility of potassium chloride in aqueous pyridine solutions of various compositions At 10° C he found the solubility of the salt to increase as the proportion of water increases, at higher temperatures complications arise owing to the separation of the liquid into two layers

Two communications by *Herz and Kuhn* [336, 337] contain their records and results of determining the solubility of mercuric halides and cyanide and of some halides of the alkali metals and of ammonium, in mixtures of ethylic and methylic, propylic and methylic, and propylic and ethylic alcohols Assuming that each constituent of the solvent exerted its solvent power independently, the solubility was calculated and compared with the solubility value found by experiment The calculated and observed values were found to agree within 10 per cent only in the case of mixtures of ethylic and propylic alcohols In other cases the divergence was greater

In the same year *Kofler* [339] published his results of measurements of the absorption coefficient of radium emanation in solutions of metallic salts

From an examination of the influence of various organic substances upon the solubility of salts which are sparingly soluble in water, *Rothmund* [343] concluded that the lowering of solubility thus occasioned is not proportional to the concentration of the substance added He observed the relationship $^1/n \log \frac{l_0}{l} = K$ (a constant) In this expression n = molecular concentration of the added substance, l_0 = solubility of salt in pure water, l = solubility of salt in mixed solvent The value of K was found to depend upon the nature of the organic substance added, with the sugars, which raise the solubility of salts, the value of K is negative The correctness of this author's conclusions was called into question by *Hudson* [343A]

1909 Further work on this subject enabled *Rothmund* [357] to conclude that the diminution of solubility of a salt brought about by the addition of a non-electrolyte is so much the greater the more effective the salt is itself in lowering the solubility of non-electrolytes This view was based upon the behaviour of a large number of different substances in changing the solubility of lithium carbonate, silver sulphate and other slightly soluble salts Unfortunately, having adopted a volume-normal basis of comparison, it is impossible to accurately judge of the relative effect produced by the added substances This author also criticised the views expressed by Hudson regarding the influence of non-electrolytes upon the solubility of electrolytes *Hudson's* [360] observations being that whilst carbamide diminishes the solubility of anhydrous sodium sulphate in water, it increases that of Glauber's salt To explain this he supposed the existence of anhydrous and hydrated molecules, and, representing the concentration of these by a and h respectively, the total solubility $s = a + h$ According as anhydrous salt or hydrated salt is the equilibrator, so either a

or h becomes constant; further, if p=the vapour pressure, then the following relationship was said to hold good

$$\frac{h}{a} = \text{const.} \times p^n$$

The addition of foreign substances diminishes p, and in consequence $\frac{h}{a}$ becomes diminished and the total solubility $a+h$ becomes decreased, if h is constant a must increase, and the total solubility is thereby increased

In the paper above referred to, Rothmund adversely criticised the views expressed by Abegg,* and also Philip's † method of estimating the degree of hydration of salts from their effect in diminishing the solubility of gases in water

Traube[350] attributed solubility-influences to "cohesion-pressure" From a study of the effect produced by non-electrolytes on the solubility of lithium carbonate, silver sulphate, and potassium bromate, he concluded that the cohesion pressure of the non-electrolyte determined the solubility of the salts ‡

The very interesting observation was made by *Pauli and Samec*[367] that proteins in aqueous solution have the effect of diminishing the solubility of easily soluble salts, such as magnesium chloride and ammonium chloride, whilst they cause an increase in the solubility of sparingly soluble salts such as calcium carbonate and calcium sulphate The influence of sodium carbonate upon the miscibility of pyridine and water was investigated by *Limbosch*[366]

An examination of the solvent properties of sulphuric acid for
1910. carbon dioxide, oxygen and nitrogen was carried out by *Bohr*[375] and the following interesting results were established Whereas these gases are practically as soluble in 96 per cent sulphuric acid at 21° C as they are in water, yet in more dilute acid solutions their solubility is much decreased, a minimum being attained at a concentration of 25/N, which corresponds with the proportion of acid to water which gives a maximum contraction when mixed together

Armstrong and Eyre[389] continued their work § dealing with the subject of the precipitation of salts from aqueous solution by alcohols,‖ their inquiry being extended to include a study of the behaviour of salts and other substances when employed as precipitants The results of chief interest were that of the three alcohols, methylic, ethylic and propylic alcohol, the first was found to be the least and the last the most active precipitant of salts The precipitating effect was always larger at 0° than at 25° C—a temperature difference which was found to be greatest for the alcohol of highest molecular weight and least for the alcohol of lowest molecular weight

The behaviour of alcohols as precipitants for metallic chlorides dis-

* *Zeitschr. f. Elektrochem.* 1901, **7**, 677.

† *J Chem. Soc* **1907, 91,** 711

‡ *Vide* Section VII

§ **A paper communicated to the *Roy Soc* in June, 1909, although not published until the following year.**

‖ *Vide* this Section 1907.

solved in water was found to be parallel to the behaviour of hydrogen chloride Glucose increases the solubility of chlorides.

The solubility of carbon dioxide in aqueous solutions of various non-electrolytes was experimentally studied by *Usher* [368A] When the solubility was calculated on a weight-normal basis he found that eleven out of the fifteen substances added to the water rendered the solution a better solvent for carbon dioxide—the substances which decreased the solubility being sucrose, glucose, mannitol and glycine The behaviour of *n*-propylic alcohol is of particular interest, inasmuch as the presence of one-half a molecular proportion of it added to 1,000 grammes of water causes the solution of 24 ccms of carbon dioxide over and above that which normally dissolves in the same weight of water

Drucker and Moles [382] determined the solubility of hydrogen and nitrogen in various mixtures of *iso*-butyric acid and water They found with these mixtures that, even at the critical solution point, the gases obeyed Henry's law

In the next year, *Sidgwick and others* [400] examined the effect produced upon the solubility of aniline in water at different temperatures by the addition of aniline hydrochloride to the mixture Very curious results were obtained, which were attributed to the great change in the distribution coefficient of the hydrochloride between aniline and water occasioned by varying the concentration of the salt

V C —*Influence of other Substances*
(iii) *Electrolytes influenced by Electrolytes*

1896 *Kuster* [12] published a criticism of the work of Fresenius and Heinz which dealt with the solubility of barium sulphate in solutions of various salts and acids, and he expressed the opinion that their results are only of qualitative value The solubility in question was considered by Kuster to be dependent upon the mass law and upon the reciprocal influence of the electrolytes in solution

1897 A particular case is afforded of the mutual influence of salts in solution where double-salts are formed, and such conditions were investigated by *Rimbach* [17] who compared the solubility of a number of double cadmium chlorides with those of their constituents At 0° C the solubility of the double-salt was found to lie between the solubilities of the constituents, but the temperature coefficient is much greater for the double-salt than for the constituent substances

The problem presented by double-salt formation was also considered by *Hoitsema* [30] in a paper dealing with aqueous solutions of two salts with one common 'ion' Considering the effect of double-salt formation in which the resultant combination dissociates into the two original salts, this author concluded that the addition of one salt must at first cause a decreased and then an increased solubility of the other salt In those cases where complex salts are formed which dissociate into fresh 'ions,' the solubility at first becomes increased and then decreased on the addition of a second salt

Ditte [20] found that the solubility of chlorides, bromides, and iodides of the alkali metals is diminished considerably by the presence of the hydroxides of these metals in the solution

An extensive communication on the solubility of mixed crystals published by *Fock*,[33] cast doubt upon the validity of Nernst's rule relating to the solubility of mixtures of salts with a common 'ion' In place of Nernst's rule that the molecular concentration of the undissociated substance is a constant quantity, he suggested that the sum of the molecular concentration of the undissociated portion and of the square of the concentration of the 'ions' is a constant *

1898 An investigation of the influence of potassium iodide and of lead nitrate on the solubility of lead iodide in water, carried out by *Noyes and Woodworth*,[45] in which they applied the principle of mass action, led them to conclude that the product of the concentration of lead 'ions' into the square of the concentration of the iodine 'ions' remains constant The theoretical aspect of this relationship was enlarged upon[48] in terms of the dissociation theory, and shortly afterwards [51] results of solubility measurements of silver benzoate in water and in aqueous solutions of nitric acid and chloracetic acid were shown to be in very fair agreement with the above hypothesis Those conclusions were verified further by *Noyes and Chapin*,[52] who studied the effect produced by sodium acetate and sodium formate on the solubility of benzoic acid in water

1899. *Meyerhoffer and Saunders* [57] studied the solubility of the reciprocal salt pair Na_2SO_4/KCl and determined what were the various solid phases which can be formed and the conditions of their existence

Grave doubt was thrown upon the general utility of Noyes' results by *Arrhenius*,[59] who proved that the undissociated portion of a sparingly soluble salt by no means remains constant, as had been assumed hitherto, during the addition of a salt containing a common 'ion' a result which, if true, entirely invalidates Noyes' method of calculating diminutions of solubility

1900 *Touren* [71] studied the variation in solubility of potassium nitrate when in the presence of potassium chloride and bromide respectively He found that equivalent—molecular—quantities of the halogen salts have equal effect upon the solubility of the nitrate, but that the nitrate and the bromide do not reduce the solubility of the chloride by the same amount Results of a somewhat similar nature to the above were published by *Winteler* [86] who carefully measured the solubility of potassium chloride and of sodium chloride respectively in solutions of potassium hydroxide and sodium hydroxide, and of sodium chlorate and potassium chlorate in solutions of sodium chloride and potassium chloride respectively *Von Ende* [85] showed that the addition of increasing quantities of hydrogen chloride or of potassium chloride to aqueous solutions of lead chloride reduced the solubility of the lead salt to a minimum, after which it increased

1901. *Groschuff*,[89] when endeavouring to determine the solubility of acid barium oxalate, found that this salt is decomposed by water; his determinations, therefore, have reference to measurements of the solubility of normal barium oxalate in presence of oxalic acid.

*** In a later publication[44A] this author again called the Nernst rule into question.**

The researches of Rudorff on the condition of equilibrium between a solution saturated with two salts and the solid solutes was extended by *Massol and Maldès* [93] Experimenting with copper sulphate and sodium sulphate these authors found the composition of the saturated solution is fixed when both salts are present in excess and the temperature is 15° C At temperatures higher than this—namely, 30° or 50°—they found that the composition of the solution varied with the relative amounts of the two solids present. It must be observed, however, that their results may have been complicated by the appearance at these temperatures of different hydrates, a possibility which they have not taken into consideration

Work was published by *Drucker* [103] which was in direct opposition to the conception of a 'solubility product '* He found that whereas potassium sulphate decreases the solubility of silver sulphate in water, sulphuric acid increases it The solubility of mercurous sulphate is also first increased and then lowered by the gradual addition of sulphuric acid

Dawson and McCrae [91] studied the influence of various electrolytes upon the distribution of ammonia between water and chloroform Carbonates and sulphates were found to have most influence, iodides, bromides, chlorates, and nitrates exerting less influence, ammonium and lithium salts were less active than potassium and sodium

Cameron [98] found the solubility of gypsum to be greatly increased by the addition of sodium chloride, a fact which explains how it is that such a relatively large proportion of gypsum is present in sea-water Magnesium chloride was found [99] to occasion a maximum solubility for gypsum, calcium chloride lowers its solubility, whilst sodium sulphate depresses the solubility to a minimum and then increases it on further addition of the salt

Enklaar [110] studied the diminution of solubility of sodium chloride when in presence of hydrogen chloride Making the assumption that both these electrolytes are equally dissociated, the solubility is stated to be correctly expressed by the following equation

$$m = -x/_2 + \sqrt{m_0^2 + x^2/_4}$$

in which x = concentration of HCl and m_0 the solubility of NaCl in pure water The solubility actually observed was always less than the calculated, and the sum $(x+m)$ is nearly a constant and equal to m_0 Similar relationships were observed with barium chloride and hydrogen chloride and with barium nitrate and nitric acid It is of interest to observe that the solubility of sodium acetate was found to be almost unaffected by the presence of acetic acid

The influence of certain fluorides on the solubility of cadmium, mercury and lead fluorides was investigated by *Jaeger* [100]

1902 Following a preliminary note† *Findlay* [144] published the application of Ramsay and Young's ‡ expression $R = R^1 + C\,(t^1 - t)$ correlating the vapour pressure of two substances, for the representation of the solubility relationship between two bodies. In this applica-

* *Vide* Nernst, Part I R 144.

† *Zeit phys. Chem*, **41**, 28. This Part, R. 127.

‡ *Phil. Mag.* [1886] (5), **21**, 33.

tion the ratios of the absolute temperatures at which the substances have an equal solubility are represented by R and R^1, C is a constant with a small positive or negative value, and t and t^1 are the temperatures at which the solubility of the second substance is known Satisfactory results were obtained with such salt pairs as zinc chloride and bromide and potassium chloride and bromide *Koppel*[130] found that the solubility of sodium sulphate is increased by the presence of copper sulphate owing to the formation in solution of a double-salt, $CuSO_4$, $Na_2SO_4.2H_2O$. *Seidell*[139] determined the solubility of various mixtures of sodium sulphate and sodium chloride at temperatures between 10° and 30°C. During their examination of the solubility of calcium carbonate in aqueous salt solutions, *Cameron and Seidell*[137] obtained some seemingly anomalous results. for instance, sodium sulphate was found to increase the solubility of calcium carbonate to a greater extent than sodium chloride, although from the great solubility of calcium chloride the reverse would not have been surprising These authors advanced a tentative hypothesis of complex 'ion' formation as a possible explanation of these results *Bodlander and Storbeck*[146] made a study of the solubility of cuprous chloride in solutions of hydrogen chloride and potassium chloride, and arrived at certain conclusions regarding the complex 'ions' which may possibly exist in such solutions They also gave values for the 'solubility product' of the three cuprous halides

Finzi[148] found that when mercuric chloride and silver nitrate solutions are mixed together a considerable quantity of silver chloride remains in solution This may be precipitated by adding any of a large number of salts, the chlorides and nitrates being particularly efficacious

The influence of salts, especially alkali nitrates, on the solubility of ammonia was examined by *Abegg and Riesenfeld*[124] In almost all cases the addition of salts was found to bring about an increased partial pressure of ammonia. In this respect, polyvalent anions have greater effect than monovalent anions, and a greater tendency to hydration of the anion occasions an increase of the partial pressure of ammonia Gaseous absorption was also investigated by *Fox*,[129] who made an extensive study of the effect produced on the solubility of sulphur dioxide in water by the addition of various electrolytes to the solvent Solutions of iodides, ammonium, potassium, and sodium bromide, potassium chloride and potassium nitrate, for example, were found to dissolve more gas than does water alone, whilst some salts, sodium chloride, sodium sulphate, calcium chloride, &c , decrease the solubility of the gas The increased solubility was attributed to the formation of complexes in solution, but it is not made clear why, for instance, this property should be attributed to potassium chloride and not to sodium chloride

Rimbach[116] determined the transformation point * of a number of double-salts including those of rubidium-cadmium and ammonium-cadmium chloride

*** The temperature at which the two solutions, saturated respectively with double salt and one of its components, become identical in composition.**

Rubenbauer[115] measured the solubility of the hydroxides of zinc, barium, tin, and lead in solutions of caustic soda of various strengths. With both zinc and lead a maximum solubility was detected, the atomic ratios being, Zn : Na = 1 : 3 and Pb : Na = 1 : 14. The diminution of solubility with greater concentrations of caustic soda was attributed to the formation of a less soluble form of hydrate owing to dehydration by the caustic alkali.

Noyes and Kohr[142] studied the solubility equilibrium between silver chloride, silver oxide, and solutions of potassium chloride and hydroxide. The values found by these authors for the solubility of silver chloride by methods of direct analysis were not in agreement with those found previously by Kohlrausch,* who employed the conductivity method. Arguing from their own observations, Noyes and Kohr concluded that silver hydroxide is not completely dissociated, as Kohlrausch assumed it to be when calculating his results, but is only dissociated to the extent of 78 per cent.

Rothmund and Wilsmore[126] contributed a theoretical discussion of the subject of solubility in which they dealt more particularly with the reciprocal nature of solubility influences.

Among those who continued the experimental investigation of the changes in solubility of salts when various proportions of acids are added to the solvent water, mention must be made of the work of *Cameron and*
1903. *Breazeale*[170]. These authors found that with low concentrations of sulphuric acid the solubility of calcium sulphate is greater than in water only. An explanation of this fact was offered by the authors, but it was not subjected to experimental verification. Soon afterwards, *Cameron and Seidel*[171] published work on the solubility of magnesium carbonate in aqueous solutions of certain electrolytes. *Herz*[183] carried out similar work to the above, employing boric acid as solute and varying the proportion of other acids, such as nitric and acetic acid, in the solvent water. In the case of sulphuric acid, nitric acid, and acetic acid he found that the solubility of the boric acid was diminished as the concentration of mineral acid was increased, but when tartaric acid was present the boric acid became more and more soluble as the proportion of tartaric acid was increased.

Herz and Muhs[155] showed that the tartrates and acetates of calcium, strontium, and barium all exhibit a maximum solubility in acetic acid solutions between the concentration 2·5 and 3·5 *N*· corresponding with the concentration which exhibits a maximum electrical conductivity. The fact of alkali formates being readily soluble in water and formic acid led *Groschuff*[152] to investigate experimentally the variations in solubility. He concluded that the increased solubility caused by the formic acid is due to the formation of acid salts, and he drew an analogy between hydrated salts and acid salts.[156]

Riesenfeld[166] continued his work which was commenced in conjunction with Abegg in the previous year,† and published further results of the research on the solubility of ammonia in aqueous salt solutions as measured by its partial pressure.

* *Vide Kohlrausch and Rose.* Part I. R. 204. † *Vide* R. 124.

Although Noyes * had apparently furnished experimental evidence of the applicability of Nernst's formula for calculating the solubility of mixtures of salts, *Bullerdieck*,[179] working under the conditions of Noyes' experiments, found evidence of the formation of complex salts in solution, thus detracting much from the importance of this application of Nernst's formula to solutions. Additional contradictory evidence was furnished by *Bogdan*,[176] who found that the solubility of boric acid in water is increased alike by the addition thereto of electrolytes and non-electrolytes.

The variableness or fixity of composition of the undissolved residue when preparing solutions saturated with two separate salts was made use of by *Foote* [172] for determining double-salt formation. From the laws regulating the solubility of substances containing a common 'ion,' it was argued that if the solid residue consists of two distinct salts, whether simple or double, their relative proportion may vary but the concentration of the saturated solution remains constant. When, however, the residue consists of only one salt, its composition remains fixed, whilst that of the solution may vary within limits, according to the relative amount of each salt originally present. Making use of this argument,[173] the author detects double thiocyanates of silver and potassium, and double chlorides of cæsium and mercury.

1904 Much attention was given in the following year to the study of solubility variations of salts as caused by the presence of other electrolytes in the solution. *Cameron and Breazeale* [204] studied the solubility of calcium sulphate in aqueous solutions of sodium and potassium sulphate, and *Seidel and Smith* [205] followed the changes of solubility of calcium sulphate in solutions of sodium and magnesium nitrate. The presence of these salts was found to occasion an increased solubility of the sulphate, but the presence of calcium nitrate conditioned a decrease.

Groschuff [188] determined the solubility of acid nitrates of potassium and ammonium in aqueous solutions of nitric acid, and discussed his results from the standpoint of the equilibrium theory.

In connection with an inquiry into the use of mercurous sulphate in standard cells, *Hulett* [202] examined the change of solubility of that salt when dissolved in sulphuric acid of various concentrations. *Auerbach* [215] studied the solubility relations of $MgCO_3,3H_2O$ and $KHCO_3$, which form a double salt of the composition $MgCO_3,KHCO_3,4H_2O$, the solubility of magnesium carbonate in the acid carbonate solution being found to increase with increased concentration of the latter up to the point at which the double salt begins to be formed.

When several salts are dissolved together in a solvent the mutual solubility influence exerted by those salts is one of the main factors determining the order of their deposition when the solvent evaporates. The problem of foretelling the order of deposition of salts from such complex mixtures was attacked by Van't Hoff and his pupils. By the application of the Phase Rule of Willard Gibbs and the skilful use of diagrams constructed from certain knowledge of the solubility of the

* *Vide* Part I. R. 164.

salts concerned, they arrived at important conclusions From time to time their results appeared in a series of papers dealing with the 'Formation of Oceanic Salt Deposits,' of which a good summary * is to be found in a publication by *Van't Hoff*[230A] himself Work upon the formation and solubility of double salts in aqueous solution was

1905. also published by *Koppel*[232] who investigated the conditions of existence of salts of the type $Na_2R''(SO_4)_2$, $x\ H_2O$, and by *Rimbach and Grewe*[221] who studied the double salts formed of cadmium halides with the halides of potassium, ammonium, and rubidium

Various examples of an increase in the solubility of slightly soluble salts when in the presence of more soluble ones have been made known *Cameron and Brown*[234] found that ammonium chloride and ammonium nitrate both increase the solubility of calcium sulphate, and *Geffcken*[245] found that salts of the alkali metals increase the solubility of lithium carbonate, and according to the observations recorded by *Kuster and Dahmer*,[247] barium sulphate is many times more soluble in concentrated solutions of chromic chloride than in water alone In the course of a study of the equilibrium relationships between the modifications of chromic chloride hexahydrate, *Roozeboom*[240] observed that the solubility of both green and violet varieties is lowered by the addition of hydrogen chloride

The 'solubility product' for silver nitrite was calculated by *Naumann and Rucker*[223] on the assumption that it is a salt which is completely ionised, but on this basis, their results for the solubility of that salt when in presence of silver nitrate were somewhat anomalous *Abegg and Pick*[224] pointed out that silver nitrite is only ionised to the extent of 55 per cent at 25° and, making this correction, they showed that the 'solubility product' is not affected by silver nitrate

From considerations based upon the dissociation theorem, *Philip*[226] was led to anticipate that the solubility of sparingly soluble acids would be increased by the presence in solution of sodium salts of weak acids This he was able to confirm, inasmuch as the formate, acetate, and butyrate of sodium were shown to increase the solubility of cinnamic, benzoic, and other acids Furthermore, the order of the increase of solubility is dependent upon the strength of the acid Work of a somewhat similar character was carried out by *Hoffmann and Langbeck*,[230] who studied how far the addition of electrolytes changed the solubility of benzoic and allied acids The initial effect was generally found to be an increased solubility of the acids, and finally their solubility was lowered by further addition of electrolyte

An investigation of the change of solubility of calcium sulphate when dissolved in solutions of ammonium sulphate was carried out by

1906 *Bell and Taber*[272] These authors were able to detect the presence in solution of a double salt, the formation of which was held to

* *Brit. Assoc Report*, 1901, Glasgow (Section B¹), by E. F Armstrong, entitled 'The application of the Equilibrium Law to the separation of crystals from complex salt solutions, and to the formation of oceanic salt deposits,' summarises this work and contains a useful explanation of the construction and interpretation of the diagrams referred to above.

explain the increased solubility of the calcium salt under the conditions above referred to Cameron and Bell[273] found that magnesium sulphate lowers the solubility of calcium sulphate, and the curve they obtained by plotting the concentration of calcium sulphate against that of the magnesium sulphate was of remarkable shape *Taber*[271] observed that phosphoric acid increases the solubility of calcium sulphate

Foote and Levy[275] made use of solubility measurements in their investigation of double-salt formation,* in the case of mixtures of mercuric chloride with the chloride of sodium potassium and rubidium In this manner several new salts were recognised

E Fischer[258] made the interesting observation that low concentrations of hydrogen chloride enhance the solubility of β-naphthalene sodium sulphonate in water, whereas greater concentrations of hydrogen chloride occasion the opposite effect

Both hydrogen chloride and sodium chloride increase the solubility of silver chloride in water, and *Barlow*[278] showed this to be an independent and, at the same time, an additive property of these substances

The solubility of plumbic sulphate in sulphuric acid solutions of various concentrations was examined by *Dolezalek and Finckh*[279]

1907 In the following year this subject was studied by *Pleissner*[318] from the point of view of its bearing upon the contamination of water supplies He found the solubility of lead sulphate and lead chloride is reduced by sulphuric acid and hydrochloric acid respectively, whilst that of the carbonate is increased by carbonic acid The influence of hydrogen chloride upon the solubility of various salts in water was studied by *H E Armstrong*, *Eyre*,[305] and others, who showed that a relatively larger effect was produced when only small quantities of hydrogen chloride were present Their results indicated a similarity of behaviour when hydrogen chloride and alcohols acted as precipitants for salts The lowering of the solubility of gases in water brought about by the addition of electrolytes and non-electrolytes (precipitants) to the solvent was examined by *Philip*,[307A] and as observed by the above-mentioned authors the lowering effect was found to be relatively most marked when dilute solutions of the precipitants were employed

The solubility of calcium carbonate in aqueous solutions of potassium chloride and potassium sulphate was measured by *Cameron* and *Robinson*[297] and *Bell and Taber*[297A] found that, up to a certain concentration, copper sulphate diminishes the solubility of gypsum, but that higher concentrations increase the solubility of the calcium salt

1908 According to *Spencer and Le Pla*[320] thallous chloride is much more soluble in solutions of potassium carbonate than in pure water, and *Free*[347] found that the addition of sodium and calcium carbonates greatly diminished the solubility of basic copper carbonate in aqueous solutions of carbon dioxide, whilst the addition of calcium sulphate produced no such effect Work having a similar bearing was published by *Kernot and Agostine*[344] in which it was shown that increasing quantities of potassium chloride at first increase and then diminish the solubility of calcium hydroxide in water. the solubility

* *Vide* **Part II. R. 172.**

ultimately being reduced below that in pure water.* In the case of barium carbonate dissolved in water containing ammonium chloride in solution, the solubility of the carbonate was found to increase as the proportion of added chloride was increased.

A discussion and criticism of the conception of a 'solubility product' as enunciated by Nernst† formed the subject of a publication by *Stieglitz* [333]. In this communication the author calculates the 'solubility product' $[C_{Ag} \times C_{acid\ ion}]$ of silver acetate, propionate, &c., when in the presence of excess of the corresponding salts, silver nitrate and sodium acetate, &c., from data furnished by the researches of Arrhenius.‡ Nernst's measurements of the solubility of silver acetate in solutions containing sodium acetate and silver nitrate (*loc. cit.*) are also recorded. The results obtained indicate that the 'solubility product' has no foundation in fact and must be regarded only as an approximate empirical principle which, in the case of the silver salts of organic acids, is sufficiently in agreement with observed facts to prove of some practical value. *Buttle and Hewitt* [322] studied the influence of silver nitrate, also nitric and hydrochloric acids, upon the solubility of silver chloride in aqueous solutions of mercuric nitrate; and *Baubigny* [325] measured the solubility of silver iodide in aqueous solutions of ammonia at various temperatures.

The solubility of the oxalates of the cerium group of elements was studied by *Hauser and Wirth* [315]. In dilute solutions of sulphuric and oxalic acids differences of solubility were observed and upon this they based a method of separating these metals.

Archibald [332] and his co-workers observed that whereas the addition of potassium chloride causes a decrease, sodium chloride causes an increase in the solubility of potassium platinichloride in water: results which are of importance in connection with analytical work.

1909. In the following year *Philip and Garner* [353] published a continuation of their work§ dealing with the influence of salts on the solubility of sparingly soluble acids. The conclusions arrived at being that sodium salts of weak acids occasion an increased solubility of sparingly soluble acids, and the weaker the acid from which the sodium salt is derived the greater is this increased solubility. Further, if of two sparingly soluble acids the stronger is the less soluble, then, under the influence of the addition of any sodium salt, it becomes more soluble. The numerical results obtained are in agreement with those calculated from Noyes' formula. *Hill and Simmons* [361] found that the laws obeyed by dilute solutions are valid for highly concentrated solutions of a salt of a weak acid in a strong acid, but the solubility of a salt of a strong acid is greatly depressed by some unexplained factor.

Kohn [363] observed that the solubility of cuprous iodide in solutions of potassium bromide increases as the concentration of the latter substance is increased.

1910. The displacement of salts from solution by various precipitants was further investigated by *Armstrong and Eyre* [389]

* *Vide Rothmund*, Z. ph. Chem., **38**, 401; *Rothmund and Wilsmore, ibid.*, **40**, 611; *Hoffmann and Langbeck, ibid.*, **51**, 385.

† Part I. R. 144. ‡ *Zeitschr. physikal. Chem.*, **31**, 197. § Part II. R. 226.

The solubility of ammonium, sodium, and potassium chlorides in dilute aqueous solutions of hydrogen chloride, potassium chloride in solutions of potassium nitrate, potassium nitrate in solutions of potassium chloride, and sodium chloride in solutions of sodium nitrate were all measured at 0° C and 25° C, and the results contrasted with similar data relating to these salts dissolved in aqueous solutions of various alcohols This work confirmed the conclusions drawn from their previous research * and showed even closer agreement in the behaviour of these different precipitants than was formerly pictured

Hill[386] measured the solubility of thallous chloride in acetic acid solutions of various strengths and of tetramethylammonium iodide in solutions of caustic potash, and the results were viewed as confirming the conclusions drawn by Cameron † and by Hill and Simmons ‡ that the 'solubility product' is not a constant quantity On the other hand, *Washburn*,[385] making use of his simplified application of thermodynamics to chemistry, claimed to have disproved the contention of Stieglitz § that the theoretical basis for the 'solubility product' is non-existent in the case of strong electrolytes, because they do not obey the law of mass action

Only brief mention can be made of the many papers bearing upon the subject of solubility variations which were published during 1910 *Van Dorp*[381] studied the system sulphuric acid—ammonium sulphate—water, and the system sulphuric acid—lithium sulphate—water, at 30° C *Beck and Stegmuller*[394] examined the influence of hydrochloric acid upon the solubility in water of lead sulphate and chromate

It was found by *Parsons and Perkins*[387] that barium nitrate and baryta mutually render each other more soluble, and the same was found to be true in the case of strontium nitrate and hydrate Similarly *Herz*[392] found the solubility of baryta was increased by the presence of alkali chlorides, but the solubility of the sulphates of potassium, sodium, and ammonium were found by *D'Ans and Schreiner*[393] to be lowered by the presence in solution of the corresponding alkali

The equilibrium relationship for the reciprocal salt pairs $KCl + NaNO_3 \rightleftarrows NaCl + KNO_3$ was determined by *Uyeda*[395] The increased solubility of silver sulphate when dissolved in presence of alkali sulphates formed the subject of an investigation by *Barre*,[373] and *Rindell*[374] studied the changes of solubility of calcium carbonate in water which are brought about by adding small quantities of ammonium salts to the solvent

Herz[390] observed that the solubility of succinic acid is lowered considerably by the presence in solution of alkali salts, the lowering effect being reciprocal The *same author*[391] found that benzoic and oxalic acids mutually render each other more soluble when dissolved together in water

1911 A research was instituted by *Noyes and others* to test the validity of the so-called 'laws' of solubility influence, (i) that the 'solubility product' of the ions is a constant, (ii) that the concen-

* Part II R 305
† Part II R 99
‡ Part II R 361
§ *loc cit* 1908.

tration of the non-ionised portion of a salt in solution has the same value in dilute solutions of other salts as when alone. In this connection *Noyes and Bray* [405] made an examination of the solubility of certain salts in the presence of some other salt which give a common 'ion' when in solution, e g. potassium sulphate and silver sulphate, and found that in all cases examined the 'ionic solubility-product' was increased so much that the 'law' was not even approximately true In some few isolated cases, recorded by *Noyes, Boggs, and others*,[406] approximate agreement was observed and the discovery of an example in fair agreement with the 'law' was published by *Bray and Winninghoff*;[407] they having found that potassium nitrate and sulphate occasion an increased solubility of thallous chloride, whilst thallous sulphate diminishes it *Bray*,[408] reviewed the work referred to above, and concluded that the concentration of the non-ionised portion of salt is not constant but usually diminishes, and the 'ionic solubility-product' usually increases His attempt to express the observed variations as functions of the total 'ion concentration' led to no real advance being made

This line of work was continued by *Harkins*,[409] who came to the conclusion that with solutions of uni-bivalent salts, the addition of a salt giving a common univalent 'ion' lowered the solubility in accordance with the principle of the 'solubility-product' The addition of a salt giving a common bivalent 'ion,' however, produced changes entirely different from those anticipated A salt with no common 'ion' always increased the solubility of the first salt Further work was published by *Harkins and Winninghoff*,[410] and *Harkins* [411] also contributed a discussion of the results from the standpoint of the 'ionic dissociation' hypothesis

With the object of testing the constancy of the 'ionic solubility-product,' *Kendall* [413] measured the solubility of sparingly soluble acids in aqueous solutions of a second acid, the experiments being ordered so as to give combinations of two weak acids, of a weak and a strong acid, and of two strong acids The results obtained showed considerable divergences from the values required by the theory of a constant 'ionic solubility-product' These differences were attributed in all cases to the solvent power exerted by the second acid in solution

Herz [417] found that hydrogen chloride and hydrogen bromide are equally effective in lowering the solubility of succinic acid in water, and, with the exception of lithium chloride, are more powerful in this respect than are the alkali salts It was observed also that tartaric and racemic acids increase the solubility of boric acid by an equal amount In a subsequent publication *this author* [418] recorded results of work dealing with the solubility of salts of the alkali metals in aqueous solutions of their corresponding acids

Masson [401] undertook an extension of the research made by Engel with the object of elucidating, if possible, the conditions governing the dissolution of salts in aqueous solutions of their acids, for those cases where Engel's rule is not obeyed He found the rule of equivalent precipitation to be of limited applicability and deduced a differential equation which expresses the relationship between the concentration of acid and of salt

Measurements were made by *Gibson and Denison* [415] of the strength of hydrogen chloride solutions necessary to cause precipitation of chlorides from their saturated solutions The experimental results obtained led these authors to conclude that the 'laws of ionic dissociation' very far from satisfactorily explain solubility phenomena, and this they considered to be due to the fact that no account is taken of hydrated ions and of undissociated molecules in solution

Mention must also be made of the study made by *Forbes* [412] of the solubility of silver chloride in the presence of many other chlorides and of the research of Barre [403] which showed that the sulphates of lanthanum and cerium are more soluble in solutions of ammonium sulphate than in solutions of either the sulphate of sodium or potassium

VI *Mutual Solubility and Distribution Coefficients*

1896 The problems presented by the distribution of a substance between two solvents continued * to engage the attention of *Jakowkin* [4] He studied the distribution of iodine and bromine between water and respectively carbon bisulphide, chloroform, &c , and found that the amount of halogen dissolved in the organic liquid and the amount dissolved in water diminish on dilution and appear to approach a limiting value It was found by *Tolloczko* [7] that when a racemic mixture distributes itself between water and an optically active solvent no separation of the racemate into *d* and *l* forms was observable

Le Chatelier [8] published a continuation of his research on the mutual solubility of salts † He found that the graphs representing melting point and composition of melted portion, showed maxima which occur usually in the neighbourhood of points where the composition is that of a definite compound and, in certain cases, for example with lithium and potassium carbonates, the maximum region is reduced to a point Some alloys also give curves of this nature It was also shown theoretically that the composition of the melted part is different from that of the mixture

The graphs for mixtures of sodium sulphate [3] with certain metallic sulphates were found to be different from those previously obtained (*loc cit*), the effect of the added sulphate being to raise, or at any rate not to lower the melting point of the sodium sulphate

In a later communication by the *same author*,[23] 1897, it was stated that mixtures of alkali sulphates with alkaline earth or other metallic sulphates form a group of mixtures which do not fall into either of the three general classes previously enumerated ‡

Aignan and Dugas [21] examined the behaviour of benzene and acetic acid when mixed together in various proportions and carefully studied the homogeneous mixtures which form at different temperatures

1898 In the following year, a summary of the previous work on the mutual solubility of liquids was given by *Rothmund* [44A] He expressed the opinion that the general form of mutual-solubility graphs for two liquids not completely miscible is a closed curve He also classified a number of liquids with regard to their mutual solubility and observed

* *Vide* Part I, R. 243, † *Vide* Part I. R. 221, ‡ *Vide* Part I. R. 221.

that the order arrived at appeared to indicate some connection between this property and the dielectric constants of the liquids. *Herz*[40] published data relating to the mutual solubility of water and respectively chloroform, carbon bisulphide, ligroin, ether, benzene, amylic alcohol, and aniline.

A communication by *Fock*[41], entitled 'Dissociation in Mixed Salt Solutions,' dealt with the solubility of mixed crystals of potassium and ammonium chloride and the author showed that, within the limits of experimental error, the Distribution Law is obeyed.

1899 The mutual solubility of methyl-ethyl-ketone and water and also in the presence of 1.5 per cent. alcohol was studied experimentally by *Bruni*[64]. He also traced the freezing-point curve for that system and found that it had no point in common with the liquid-solubility curve.

Lotmar[65] found that p-nitrophenol towards the systems water-benzene, water-chloroform, &c., exhibits a partition relationship which is almost independent of temperature, and which is different from the relationship which exists between its solubilities in the separate solvents.

When aniline and water are mixed together *Aignan* and *Dugas*[56] found that there is no change of volume consequent on the reciprocal solubility of the liquids, although in the case of amylic alcohol a volume change was observed.

1900 *Newth*[70] found that if ordinary strong aqueous ammonia and a saturated solution of potassium carbonate be shaken together two layers are formed. Calling the original solutions A and B, the two layers are saturated solutions of A in B, and B in A respectively. It was found that by adding suitable quantities of water, mixtures could be obtained which were critical for any desired temperature.

Van der Lee[73] investigated the influence of pressure on the mutual solubility of water and phenol. The results found showed that increased pressure raises the critical point in accordance with the requirements of Van der Waal's theorem when applied to solutions. *Dawson and*
1901 *McCrae*[92] examined the distribution of ammonia between water and chloroform at 15° and 30° C. For solutions less than 0.5 N, the distribution coefficient

$$\frac{\text{conc. of } NH_3 \text{ in water}}{\text{conc. of } NH_3 \text{ in chloroform}}$$

is constant at constant temperature, but, for solutions of greater concentration it falls. If copper sulphate be dissolved in the water, the coefficient rises owing to the 'fixation' of the ammonia by the copper
1902. salt. Extending this work to the investigation of the distribution of acetic acid between water and chloroform *Dawson and Grant*[120] found that the ratio varies greatly with concentration, but is little affected by the presence of sodium acetate or tartaric acid.

In the course of experiments on the distribution of iodine between water and a mixture of two organic solvents, *Dawson*[122] found the solvent power of such a mixture to be generally less than that which is calculated from a knowledge of the solvent powers of the liquids on the assumption that they form a simple mixture. In the case, however, of

carbon bisulphide with benzene and toluene the solvent powers of the mixtures were found to be greater than would be expected on the above assumption.

The distribution coefficient of sulphur dioxide between water and chloroform was found by *McCrae and Wilson*[181] to vary with the concentration. This fact they attributed to the varying degree of electrolytic dissociation of the sulphurous acid and cited the experimental fact that hydrogen chloride diminishes the distribution coefficient as being in support of their suggestion. Results not in harmony with this view were published by *Farmer*[161] who found the coefficient of distribution of benzoic acid between benzene and water to be but slightly changed by the addition of either potassium benzoate or sodium acetate to the aqueous layer.

1903

Vaubel[187] found that in certain cases the distribution coefficient of a substance between two solvents is a function of the relative volumes of the latter. This was found to be true in the case of phenol dissolving in water and benzene or chloroform, *m*-cresol dissolving in water and ether, aniline dissolving in water and ether or chloroform, &c. With the system resorcinol dissolving in water and ether or benzene, however, the coefficient was observed to be independent of volume changes.

1904 *Vezes and Mouline*[208] observed aqueous alcohol to be much less soluble in turpentine oil than is that oil soluble in aqueous alcohol at the same temperature.

Hudson[194] made the important observation that the complete water-nicotine solubility curve is a closed one; above 210° and below 64° the two liquids are completely miscible; at about 90° the two layers have equal density; above 90° the nicotine forms the upper layer and below 90° it forms the lower layer.

The distribution of a number of acids and bases between water and amylic alcohol was studied by *Herz and Fischer*[189]. These authors worked with acids such as phenol, acetic, oxalic and picric acids, and bases such as ammonia, methylamine and triethylamine. Generally speaking the results obtained indicate that for weak electrolytes the distribution ratio is independent of the concentration, but that with more highly dissociated compounds, for example, oxalic and picric acids, a constant is obtained only for the undissociated portion.

1905 The liquid-pair diethylamine and water were found by *Lattey*[237] to be completely miscible only below 143.5°C. Above that temperature two layers are formed.

The distribution of soluble substances between water and various aromatic hydrocarbons has been studied by *Herz and Fischer*[220] who found that a constant value for the distribution ratio is obtained when allowance is made for (i) electrolytic dissociation in water, (ii) association in the hydrocarbon.

1906 *Riedel*[269] observed that the partition coefficient of aniline between water and toluene varies with the concentration, and as an explanation of this fact, suggested that when dissolved in toluene, aniline may exist to some extent in the condition of duplex molecules, the proportion of duplex to simplex molecules varying with the concentration.

Buchner[270] discussed the limited miscibility of liquids and the

manner in which this is affected by temperature, pressure, and concentration. With regard to temperature he distinguished the following cases: (i) Increased miscibility with falling temperature. (ii) Increased miscibility with rising temperature and one liquid phase becoming identical with the vapour. (iii) Increased miscibility with rising temperature and the two liquid phases becoming identical.

The reciprocal solubility curve for oil of turpentine and methyl
1907. sulphate was found by *Dubroca* [314] to be of the usual parabolic form, the apex of the parabola being the critical point and the axis being practically parallel with the temperature axis.*

From an examination of the conditions under which liquids are miscible, *Bingham* [299] was led to call attention to the fact that, although substances of small molecular volume are usually miscible with others of small molecular volume, they are immiscible with those of high molecular volume. Thus, for example, water is only partially miscible with intermediate alcohols and immiscible with higher alcohols. In a later paper this author [300] dealt with this matter from a theoretical point of view.†

Smirnoff [291] studied the distribution of the hydrates of stannic chloride between water and xylene at various temperatures and from certain irregularities of the distribution coefficient he arrived at conclusions regarding the dissociation of the salt in water.

The critical phenomena exhibited by solutions of some organic substances, such, for example, as phenanthrene, anthraquinone and triphenylmethane in *iso*-pentane formed the subject of investigation by
1908 *Centnerszwer and Kalnin* [295]. *Flaschner* [327] studied the mutual solubility of homologous piperidines and besides ascertaining that piperidine and water are completely miscible at temperatures between 0° and 250°, obtained indirect evidence of a lower critical temperature. Methyl piperidine and water were found to have a lower critical temperature of 48·3°, and for ethylpiperidine the critical temperature was 7·4°. In a subsequent paper *Flaschner and McEwen* [321] discussed the problem of mutual solubility from the point of view suggested by Rothmund—namely, that the complete mutual solubility curves of a pair of liquids form a closed solubility ring. The conclusion arrived at was that all such solubility rings which represent the behaviour of one liquid (water, for example) with members of an homologous series, have a common centre: the higher the member of the series the less the mutual solubility and consequently the wider the solubility ring. The influence of chemical constitution upon mutual solubility was also discussed in that paper.

The distribution of various solutes between water and various soils was studied by *Cameron and Patten* [330]. The soil acts as an absorbent, and for any series of soils, the order of absorptive capacities for any one solute was found to be quite different from the order for another solute.

1909 *Timmermans* [365] showed that the degree of miscibility of two liquids is a function of the external pressure.‡ *Limbosch* [366] investigated the changed miscibility of pyridine and water which is brought about by the addition of sodium carbonate.

* *Vide Rothmund*, Part II. R. 44. † *Vide* Section VII.

‡ *Vide* Part II., Section V. B.

From a study of the distribution of iodine between pairs of non-miscible organic solvents, *Landau*[380] concluded that when the solute exists
1910. in the same state in both solvents, then the distribution ratio is a constant, but, if in one of them the state of aggregation of the iodine is different from its state of aggregation in the other, then the ratio is dependent upon the concentration of the solute

Herz and Kurzer[396] studied the more complex case of the distribution ratio of various solutes as between two liquids of which one was a mixture of two solvents In general the mixture was found to behave as a homogeneous liquid when allowance was made for association or dissociation of solute in the solvents

1911. *Sidgwick*[400] and others found that the distribution of aniline hydrochloride between aniline and water varies very considerably with change of concentration The distribution ratio of ammonia between water and chloroform was found by *Bell and Field*[404] to be much lower in concentrated than in dilute solutions and the ratio to be changed but slightly by the addition of ammonium chloride *Kolossovsky*,[423] on the other hand, found the distribution ratio of acetic acid between water and ethylic ether to be generally lowered by the addition of salts

VII —*Theoretical Considerations*

In Part I of this Report* reference was made to the view expressed by *Arctowski*, that when one substance dissolves in another it does so by virtue of its property of forming molecular compounds with the solvent
1896. In a subsequent communication *this author*[13] urged the desirability of studying the simplest cases of dissolution, namely, that of a solid substance dissolving in a gas, as the best means of obtaining knowledge respecting the laws of solubility From this point of view he contributed results of measurements of the velocity of sublimation of the three mercuric halogen salts, and expressed the opinion that such measurements, being measures of the vapour tension of the solid substances, may be regarded as indicative of their solubility in the gas

Speyers[11] published a discussion of the nature of liquids in which he approved the practice of viewing a liquid as a condensed gas, at the same time recognising that besides being compressed into smaller compass it carries gaseous activity—pressure—with it into the liquid condition He looked upon a dissolved substance as being brought into the same condition as the liquid, and capable also of exerting a pressure

An investigation of the distribution of iodine and bromine between water and certain organic solvents led *Jakowkin*[4] to recognise a change in the distribution coefficient with increased concentration, and this he attributed to the existence in the organic solvent of associated molecules The non-obedience of Henry's law of solutions of carbon-dioxide was also attributed to the existence of duplex molecules of solute when in the gaseous state, and only simplex molecules when in solution.

* *Vide* Part I. R. 209.

Bancroft [9] discussed the question of the identity of fusion and solubility curves, and adduced evidence in support of his contention that they are not to be considered as identical

1897 *Stortenbecker* [22] continued his studies of mixed hydrated crystals,* and concluded that it is not permissible to regard the isolation of any particularly stable hydrate as connoting the existence of the solute solely in that state of hydration other less stable hydrates must be recognised as being present in solution Other views in favour of union taking place between solvent and solute are to be found in a publication by *Talmadge*,[37] which deals with the solubility of solids in vapours

McIntosh [34] studied the solubility of mercuric chloride, it having been observed previously that the solubility graph exhibits a break at a temperature which is different with different solvents It was pointed out that this should not be the case if the change of direction of the curve is due to a change from one modification of mercuric chloride to another The author found that from a solution in methylic alcohol a compound $HgCl_2,CH_3OH$ crystallises out below 35° C., and he considers it probable that the salt forms similar compounds with other solvents A further publication [36] by the same author is devoted to a general discussion of the relation between solubility and freezing-point

The problems presented by the dissolution of an electrolyte in a solution of another electrolyte—both of which give an 'ion' in common when in solution—were discussed by *Hoitsema* [30] from the standpoint of the electrolytic dissociation hypothesis He concluded that unless interaction occurs between the two substances the concentration of the one must be lowered by the addition of the other, but that it cannot sink below the value for the non-dissociated part of the salt

Fock [33] brought forward results of an investigation of the equilibrium obtaining between saturated solutions of a number of pairs of isomorphous salts and showed that Nernst's law of solubility is incorrect, saturation being dependent upon both dissociated and undissociated salt In place of Nernst's law that the molecular concentration of the undissociated portion is constant, it was suggested that the sum of the concentration of the undissociated and the square of the concentration of the 'ions' is constant

The soundness of Nernst's law was further contested by *Fock* [44]

The equation given by Jahn† representing the absorption of gases by solutions of electrolytes was subjected to exhaustive tests and confirmed by *Roth* [29]

Noyes and Whitney [27A] regarded solubility as a diffusion phenomenon They measured the rate of dissolution in water of benzoic acid
1898 and of lead chloride when in stick form, and concluded [50] that the rate at which a solid substance dissolves in its own solution is proportional to the difference between the concentration of that solution and the concentration of the saturated solution *Noyes and his collaborators* [45, 52] gave considerable attention to the verification of the theory of solubility influence as deduced from the electrolytic dissocia-

* *Vide* Part I. R. 238. † *Vide* Part I. R 240.

tion theory and the law of mass action Their experimental results were found to be in fair agreement with the requirements of that theory

Dahms [44] published a thermodynamical discussion which led him to results in support of the general law of solubility enunciated by Schroder and Le Chatelier * *Goldschmidt* [43] tested the accuracy of the formulæ representing molecular solubility changes proposed by Van't Hoff and Van Laar, and found the degree of dissociation was not the same as that which is calculated by means of either formula, neither was the heat of solution in agreement with the calculated values

The relation between solubility and heat of formation of electrolytes formed the subject of a discussion by *Bodlander* [47] He found the solubility of different salts of the same metal to be greater the greater the tendency for the acid radicle to pass into the 'ionic state' With different salts of the same acid similar observations were made, namely, that the solubility is greater when there is a greater tendency for the metal to pass into the 'ionic state' These facts were explained by reference to variations in the heats of formation of the salts

Evidence in favour of a theory of solubility based upon association was published by *Brown*,[49] who made the interesting observations that the boiling-point of 50 per cent alcohol is not raised but is lowered by the addition of potassium chloride, and carbamide, which is equally soluble in water as in alcohol, raises the boiling-point of 50 per cent alcohol

1900 *Rothmund* [72] pointed out that notwithstanding the results obtained by Gordon, Roth, Euler, and others, many scientists still assume that the addition of a salt has no effect on the solubility of a non-electrolyte A study of the influence of salts on the solubility of phenylthiocarbamide furnished additional evidence in contradiction of such an assumption

The conclusion of Noyes and Whitney that dissolution is a diffusion phenomenon was supported by the work of *Bruner and Tolloczko* [78] on the rate of dissolution of benzoic acid and of gypsum

Stortenbecker [75] continued his studies of mixed hydrated crystals, dealing with cadmium and ferrous sulphate, and copper and manganese sulphate

The increased solubility of the carbonates of the alkaline earth metals when in the presence of carbon dioxide is well known, *Bodlander* [77] showed how this can be calculated at different pressures of carbon dioxide from a knowledge of the solubility of carbon dioxide in water, the conductivity of the solution, the dissociation of the water, and the solubility of the carbonate in pure water

In a publication dealing with 'The relation of ammonia to salts in aqueous solution,' *Konowalow* [80] criticised vehemently the dissociation theory of solutions, and insisted upon the formation of hydrates in solution

Further confirmation of Jahn's equation for gaseous absorption was furnished by the research of *Levi* [107] It was found to express the
1901. relationship obtaining when nitrogen dissolves in solutions of methylic alcohol containing an electrolyte (potassium iodide) or a non-electrolyte (carbamide)

* *Vide* Part I R. 202 and 221.

From a study of the influence of various electrolytes on the distribution of ammonia between water and chloroform, *Dawson and McCrae* [91] were led to conclude that the solvent power of water is changed to a varying extent by the different 'ions' present *Cameron* [98] regarded the peculiar effect on the solubility of gypsum produced by common salt as being inexplicable by the current hypotheses regarding solutions.

Enklaar [110] endeavoured to explain the anomalous solubility of sodium chloride when in the presence of hydrogen chloride on the possibility of a change of volume of the water being conditioned by the 'ions' of the hydrogen chloride

The conclusion of Étard * that the temperature-solubility graphs for salts are straight lines if the solubility is defined as the weight of salt in 1,000 grms of saturated solution was shown to be erroneous by *Cohen and Buchner.*[109]

Nernst [97] contributed a theoretical and mathematical discussion of solubility in which he made use of Wilsmore's experimental results

The manner of representing mathematically the velocity of dissolution formed the subject of a controversy between Drucker and Bruner and Tolloczko *Drucker* [94] considered that the formula proposed by Noyes and Whitney was insufficient, inasmuch as it does not take into account the volume of the solute, and he deduced a more general formula. *Bruner and Tolloczko* [102] endeavoured to show that Drucker's conclusions were vitiated by experimental error, and he, in reply,[104] refused to regard the constants of the Noyes-Whitney formula as diffusion constants

The process of dissolution was defined by *Wyrouboff* [101] as the disaggregation, or the setting at liberty of the molecules of a solid substance Seeing that this change must be accompanied by absorption of heat, those cases of dissolution where the reverse takes place were concluded to be accompanied by secondary phenomena, such as polymorphous changes, combination with solvent, &c

1902. A theoretical discussion of solubility graphs was published by *Lumsden* [119] The factors which condition the solubility of a substance were considered to be (i) affinity between solvent and solute, (ii) thermal energy of the solid; (iii) pressure of dissolved particles—osmotic pressure—all of which vary with change of temperature and pressure Normal solubility graphs were stated to be those which are convex to the temperature axis, although graphs showing a diminution of solubility with rise of temperature and then an increase, were not considered to be anomalous such graphs being only peculiar in having the descending portion come within the observed range of temperature

The reciprocal nature of solubility influence was discussed by *Rothmund and Wilsmore* [126] They deduced that if the solubility of a substance A is lowered by the addition thereto of substance B, then that of B must be lowered by the addition of A If L_1 and L_2 represent the solubilities of the pure substances and l_1 and l_2 the solubilities in a saturated solution of both, then

$$l_1 \log \left(\frac{L_1}{l_1}\right) = l_2 \log \left(\frac{L_2}{l_2}\right)$$

Findlay [144] applied to the case of solubilities the equation* $R = R' + C (t' - t)$ developed by Ramsay and Young† to represent the relation between the vapour pressure of two substances He found that if the solubility graph of one substance is known, then if two observations of solubility of the second substance at different temperatures are made, the solubility of the second substance at any absolute temperature can be calculated. This method was adopted in the case of several salt pairs,[127] also when measuring the solubility of mannitol, picric acid, and anthracene,[123] and was extended to other cases in a later publication [131]

The application of the electrolytic dissociation hypothesis to the calculations of solubility from conductivity measurements is liable to lead to erroneous results, and this is clearly shown by the work of *Noyes and Kohn* [142] Kohlrausch, when calculating the solubility of silver chloride by the method referred to, assumed that silver hydroxide is completely dissociated in solution by direct analysis Noyes and Kohr, however, obtained results which were not in agreement with Kohlrausch's and which led them to conclude that the hydroxide is only dissociated to the extent of 70 per cent

The relationship between freezing point, boiling point and solubility was discussed by *Wildermann*,[136] and as a result, this author devised certain mathematical equations from which the solubility graphs for a substance dissolving in water could be calculated

Lumière, Lumière and Seyewetz [150] made the interesting observation that the solubilities of trioxymethylene and sodium sulphite in water are increased by the presence of each other, and they suggest this may be due to partial depolymerisation taking place in the solution

1903. The subject of the velocity of dissolution was again taken up by *Bruner and Tolloczko* [185] They experimented with alabaster and gypsum and found that the velocity is not a linear function of time, as Drucker deduced, but in the case of alabaster is a logarithmic function

An experimental examination of the thermodynamical relation between the heat of solution and change of solubility with temperature in the case of dissociated substances was undertaken by *Noyes and Sammet* [163] They made use of *o*-nitro-benzoic acid and potassium perchlorate, and although the results obtained in the case of the former substance were not in good agreement, those with potassium perchlorate were in approximate agreement with the requirements of Van't Hoff's equation, so these authors expressed the opinion that electrical conductivity is a correct measure of dissociation

According to *Bogdan*,[176] non-electrolytes increase and electrolytes diminish the solubility of phenylthiocarbamide, whereas both electrolytes and non-electrolytes increase the solubility of boric acid This author contributed also a lengthy discussion of the theories of Jahn and Nernst

* In this equation R and R′ represent the ratios of the absolute temperatures at two points of equal solubility of the substances, c is a constant and t' and t are the temperatures at which the solubility of the second substance is known.

NOTE —*Meyerhoffer*[181] credited Kopp (*Vide* Part I. R 10) with the discovery that each hydrate of a salt has a definite solubility graph. *Ostwald*,[135] however, attributed this discovery to Gay-Lussac.

† *Vide Phil. Mag.*, **21**, 33.

The complex problem presented by the dissolution of homogeneous mixtures was investigated by *Thiel* [161] He distinguished five different cases, gave examples of each, and considered how the solubility varies with the composition of the solid mixture

McLauchlan [165] attempted to explain the results of his work on solubility influence* on the basis of chemical interaction taking place in solution

Determinations of distribution coefficients carried out by *Vaubel* [187] led that author to conclude that the abnormalities he observed were due to the formation of hydrates in solution

The opinion is held by some chemists that, in the case of slightly soluble substances, electrical conductivity may be regarded as a measure

1904. of solubility,† and for the purposes of such calculations Kohlrausch published a large number of conductivity measurements ‡ *Gardner and Gerassimoff* [199] pointed out that in the case of salts which are easily hydrolysed the above assumption is not true, and in support of their statement quoted the fact that the conductivity of barium carbonate is lowered by the presence of sodium hydroxide, whereas that of barium sulphate remains unchanged

When a gas dissolves in a liquid, Henry's law is obeyed provided the gas is not dissociated in solution, or if it associates with the solvent, it does so in such a manner that each aggregate contains only one molecule of the dissolved gas § For those cases in which the gas is dissociated in solution *Richardson* [214] arrived at a suitable equation for calculating the solubility a mathematical expression correlating variation of solubility with change of temperature was obtained, which is dependent solely on the difference of the heats of solution of the dissociated and undissociated gas

Schurr [219] investigated the problem of the rate of dissolution of salts In his studies, all but one of the crystal facets of the solute were covered by paraffin,|| and he was able to detect three different periods of dissolution The rule of Noyes and Whitney was found to be true only for sparingly soluble substances In the following year *Bruner and*

1905 *Tolloczko* [233] criticised these suggestions and reaffirmed the formula proposed by Noyes and Whitney

On the basis of Jahn's theory, *Hoffman and Langbeck* [230] derived formulæ from which it is possible to calculate the effect of various electrolytes and non-electrolytes upon the solubility in water of benzoic and allied acids

In addition to the many attempts made to arrive at a mathematical expression which would properly represent solubility relationship for more than a few chosen cases, a good deal of attention centred on the association theory of solution *Lowry* [228] attempted to extend the con-

* *Vide* V. c. ii.

† From time to time attempts have been made to compute the degree of dissociation from solubility graphs—*vide Kremann* (Monatsh, **25**, 1215; Zeitschr Elektrochem, **12**, 259); *Roozeboom and Aten* (Zeitschr physikal. chem, **53**, 463); *Van Laar* (Proc. K Akad Wetensch. Amsterdam, **8**, 699); *Findlay and Hickmans* (J. Chem Soc, **91**, 905).

‡ *Vide* II. R 203

§ *Vide* Van't Hoff's Lectures on Theoretical Chemistry, Part II, p 28

|| *Vide* Part I R 56 and 59.

ception of hydration in aqueous solution so as to embrace the idea of dissociation by suggesting that hydration may go so far as to separate the solute into two or more hydrated 'ions'.

This view of the changes taking place on dissolution was criticised by *Dreaper*,[229] who maintained that hydration does not completely sever the primary bond between the elements.

Jones and Basset[231] considered the fact of the amount of water of crystallisation being a function of the temperature to be a strong argument in favour of the view that salts dissolve by virtue of their power to combine with the solvent.*

When criticising Roozeboom's explanation of some peculiar solubility graphs† on the assumption of hydrate formation, *Van Laar*[256] expressed the opinion that hydration must be attributed mainly to the 'ions' if the peculiarities referred to are to be explained adequately.

Schiller[254] also contributed a mathematical paper dealing with the reciprocal behaviour of solvent and solute.

1906 *Winkler*[262] continued his work on the absorption of gases in water at different temperatures, and established the relationship which he had already discovered between the absorption coefficient of a gas, its molecular weight and the internal friction of the water. *Rex*[263] studied the solubility of halogen derivatives of hydrocarbons and concluded that the dissolution of these substances in water is a process of absorption just as in the case of the absorption of a gas. This author also found the value k in Winkler's formula‡ increases with temperature, and when calculated for each of a series of derivatives increases regularly with the atomic weight.

An attempt was made by *Walden*[266] to find some general relationship between solvent and solute. He examined the solubility of a number of tetralkylammonium halides in various organic solvents,§ but his results did not seem capable of general interpretation in terms of any particular theory. The observation that saturated solutions of tetramethylammonium iodide in various solvents are all dissociated to the same extent—have equivalent molecular conductivity—appeared to be of some significance.

Smirnoff[283] studied the separation of liquids into layers—salting out phenomena—and concluded that the added salt becomes associated with the solvent.

The observation made by *Fischer*[258] that hydrogen chloride at first raises, and then with increasing concentration lowers the solubility of β-napthalene sodium sulphonate is in agreement with the results obtained by Noyes. Fischer attributed the subsequent lowering of solubility to the withdrawal of water from solvent action by the hydrogen chloride, or to some considerable change in the solvent medium.

Longinescu[282] considered dissolution to be a purely physical phenomenon. He found a criterion for the solubility of organic compounds in water in the magnitude of the ratio of the absolute boiling-point to the molecular weight. If this ratio is greater than 5 for any substance, then

* Arguments similar to these had been published previously (1904) by *Jones and Getmann*[206].

† *Zeitschr. physikal. Chem.*, **53**, 449.

‡ *Vide* Part I. 190.

§ Compare Sections III. B. and IV. B.

the substance is soluble in water; if it is less than 3·5, then it is not soluble.

An important paper on solubility was contributed by *Levin* [264]. He critically reviewed previous work and came to the conclusion that non-electrolytes do not appreciably change the solubility of a substance. With regard to salting-out phenomena, he was not in agreement with the conception of an 'internal pressure,'* nor with Rothmund's assumption of a combination between solvent and solute, but supposed the lowering of solubility to be due to the mutual action of the two solutes upon each other. *Trevor* [271] published a purely mathematical investigation of certain solubility graphs.

Shinn [296] made the important observation that in passing from liquid ammonia to amylamine as solvent for salts there is a reversal of the
1907. usual relation between molecular conductivity and dilution. For example, in ethylamine and amylamine the molecular conductivity decreases with increased dilution, a fact which, from the standpoint of the electrolytic dissociation theory, was considered to be inexplicable.

As the result of studying the precipitation of salts from solution by non-electrolytes and by electrolytes under identical conditions *Armstrong and Eyre* [305] observed a general similarity in the behaviour of these substances towards electrolytes in solution. From solubility measurements they concluded that the condition in which salts exist in concentrated aqueous solutions is different from that which they assume when in the presence of a considerable quantity of a precipitant.

Philip [307] expressed the opinion that substances when dissolved in water are frequently hydrated, and he considered that the degree of hydration of an added substance could be calculated from the difference between the solubility of a gas in water and in a solution of the added substance.†

From an examination of the action of salts in causing mixed liquids to separate into layers, *Smirnoff* [317] supposed the 'ions' of the solute become associated with the solvent. *Bingham* [300] investigated a similar phenomenon—namely, the miscibility of liquids—and suggested that this is dependent upon the attractions between the particles, and he adduced evidence to prove that the molecular attractions are inversely proportional to the molecular volumes.

Ostromysslensky [319] classified organic solvents according as (*a*) their solvent power is independent of the constitution of the solute—*e.g.* water, ether alcohol, &c.—or (*b*) their constitution must be related to that of the solute. *Magie* [304] pointed out how the properties—heat capacity and volume of a solvent—are changed by the presence of a solute and advanced an association theory of solutions.

Parsons [298] drew attention to the case of the dissolution of a substance in a mixture of two substances with one of which it is immiscible. It was argued that a solid, when in solution may, and frequently does, act towards other solutes exactly as if it were a liquid miscible with the liquid in which the second solute is itself soluble. The assumption

* *Vide* Part II. Section V. C. (ii) R. 200 and 201.

† *Vide* also a supplementary publication by the same author.[307A]

that complexes are formed was held to be frequently unnecessary as an explanation of solubility phenomena

In connection with the velocity of dissolution, *Bruner and Tolloczko* [312] confirmed the Noyes-Whitney formula, not only for slightly soluble substances, but even for solutes such as sodium chloride

The 'ionic dissociation' theory of solution was strongly attacked by *Armstrong*,[334] who advanced evidence and argument in favour of the view that union takes place between solvent and solute It was insisted upon that the solvent must be regarded as playing an important part in conditioning dissolution, and that the molecular complexes which constitute solids and liquids become simplified For example, water is considered to be an equilibrium mixture represented by $(H_2O)n \rightleftarrows nH_2O$, and the simplex molecular H_2O, called hydrone, is regarded as being the active agent* effecting dissolution

Rothmund [343] published a paper dealing with solubility influences and discussed the evidence he had obtained when using aqueous solutions of slightly soluble salts, and previous work relating to experiments with more soluble salts The conclusions he came to were that the nature of this influence of non-electrolytes on the solubility of electrolytes depends upon the individual character of the substances in solution—upon some interaction between them, and not between solvent and solute

1909 It was demonstrated by *Timmermans* [365] that the mutual solubility of two non-miscible liquids depends upon the external pressure, and that it is possible to pass continuously from dilute to concentrated solutions by varying the pressure On the basis of this fact the author proposed to elaborate a theorem, applying to concentrated solutions the conceptions of Van der Waals

Hudson [360] developed a theory of solution in which he supposed hydrated and anhydrous salt capable of existing together in solution † *Gillet* [364] also favoured an hydration theory of solution, he supposed water to be a mixture of dihydrol and hydrol—$(H_2O)_2 = H_2O^+ + H_2O^-$—and considered all aqueous solutions to be compounds of solute with either positive H_2O^+, or negative H_2O^-, hydrol

A paper dealing with complex mathematical equations respecting the representation of solubility influences, published by *Rothmund*,[357] contained also observations on the diminution of solubility of a salt as caused by the presence of non-electrolytes This author considered Philip's method of calculating hydration values (R 307) to be indefensible, and also adversely criticised the views expressed by Abegg‡ and by Hudson (R 360) *Traube* [348] maintained that quite irrespective of any question of quantitative correctness in certain cases, the electrolytic dissociation hypothesis is based upon a fundamental error inasmuch as no regard is paid to the 'intensity factor'§ This factor he called the 'cohesion

* *Vide Armstrong* on 'The Origin of Osmotic Effects,' *Proc. Roy. Soc.*, **78**, 264.

† *Vide* Section V., C. ii.

‡ *Zeitschr. f. elektrochem.* (1901), f 677.

§ In connection with these and similar views, reference should be made to the paper by *Bose and Bose* (Zeitschr. physikal. chem., **69**, 58) dealing with the localisation of molecular forces and a discussion of the attractive constant *a* of Van der Waals' equation.

pressure '* of the solution and defined it[383] as the force with which the solute is retained in solution. It was stated that of two substances
1910 possessing the same internal pressure, that one is the more soluble which can exert a greater cohesion pressure. The difference between the surface tension of a solvent and a solution was regarded as a measure of the cohesion pressure of the solute.

Armstrong and Eyre[389] were able to explain the results of their further research on solubility influence on the basis of Armstrong's theory of solution.† Precipitation of salts by alcohols was held to be due to dehydration changes conditioned both by the direct removal of water from solvent action by the precipitant, and particularly with neutral precipitants, by the increased proportion of 'hydrone' molecules produced in the water by the mechanical interposition of the precipitant molecules. The increased solubility of salts when in the presence of sugar was considered to be due to combination taking place between salt and sugar.

Usher[368A] concluded that the effect on the solubility of a gas produced by non-electrolytes is not capable of explanation by reference either to the formation of hydrates in solution or deviations from the theory of osmotic pressure, and claimed that his results showed that, to express the solvent properties of solutions, any conclusions depending on the assumption that the dissolved substance has no solvent power are worthless.

Above the critical temperature *Tyrer*[370] observed the solubility of a substance to be dependent upon the concentration of the solvent, as would be expected if solubility is dependent upon an attractive force acting between solvent and solute. He[372] was led from this observation to suppose that in all cases solubility is some function of the concentration of the solvent and sought to ascertain by experiment with organic substances what that function may be. No simple general rule was discovered, however.

According to *Gibson and Denison*[115] the electrolytic dissociation theory in no way explains the facts they observed respecting the strength of hydrochloric acid necessary to precipitate chlorides from solution, and this they consider is because no account is taken of hydrated ions and undissociated molecules.

Hill[386] published a paper which dealt with the inconstancy of the
1911 'solubility product,' and in the following year additional discredit was cast on this principle by the research of *Kendall*[113].

Noyes,[405, 406] in conjunction with *Bray*[407, 408] and others, made an investigation of the so-called laws of solubility influence and disproved two of them which he claimed to have established in 1895.‡

NOTE.—In 1909, H. C. Jones[158] published a paper entitled 'The present status of the Solvate Theory,' in which he reviewed the work done by himself and his co-workers during the past ten years.

* For further information respecting the researches and the views held by this author, reference should be made to *Ber.*, **17**, 2304; *Pfluger's Archiv f. Physiologie*, **105**, 541 and 549; **123**, 419; *Archiv f. Pathologie*, II., 117; *Deutsch. medic. Wochenschrift*, Nr. 28; *Verh. deutsch. physik. Gesell.*, **6**, 326; *Biochem. Zeitschr.*, **10**, 371.

† *Vide* this Section, R. 305 and 334. ‡ *Vide* Part I. R. 228.

He realised that other influences had to be taken into account, and attempted to express the observed variations as functions of the total 'ion concentration' Somewhat similar results and conclusions to these were published by *Harkins* [409]

VIII —*Chronological Bibliography*

No	Date	Author	Reference	Section
1	1896	Walden . .	'Ber ,' **29**, 1692	IV A
2		Parmentier	'Compt rend ,' **122**, 135	IV A
3		Le Chatelier	'Compt rend ,' **123**, 746	VI
4		Jakowkin .	'Zeitschr physikal. Chem ,' **18**, 585	V B , VI., VII
5		Stackelburg	'Zeitschr physikal Chem ,' **20**, 337	V B
6		Tolloczko	'Zeitschr physikal Chem ,' **20**, 389	V C i
7		Tolloczko	'Zeitschr physikal Chem ,' **20**, 412	III A , IV A , VI
8		Le Chatelier	'Zeitschr physikal Chem ,' **21**, 557	VI
9		Bancroft	'J Phys Soc ,' **1**, 137 . .	V A i , VII
10		Bathrick	'J Phys Chem ,' **1**, 157 .	V C ii
11		Speyers	'J Amer Chem Soc ,' **18**, 724	VII
12		Kuster	'Zeitschr anorg Chem ,' **12**, 261	V C iii
13		Arctowski	'Zeitschr anorg Chem ,' **12**, 413	III A , VII
14		Weisberg	'Bull Soc Chim ' (3), **15**, 1247	V C. ii
14A		Walter	'J prkt Chem ,' (2), **53**, 132	II C
15	1897	Mylius&Funk	'Ber ,' **30**, 824	IV C
16		Mylius&Funk	'Ber ,' **30**, 1716	IV C
17		Rimbach	'Ber ,' **30**, 3073	V C iii
18		Tutton .	'J Chem. Soc ,' **71**, 850	IV C
19		Kipping&Pope	'J Chem Soc ,' **71**, 998	IV A
20		Ditte .	'Compt rend ,' **124**, 29	V C iii
21		Aignan and Dugas	'Compt rend ,' **125**, 498	VI.
22		Stortenbecker	'Zeitschr physikal.Chem ,' **22**, 60	VII
23		Le Chatelier	'Zeitschr physikal Chem ,' **22**, 250	VI
24		Bodtker	'Zeitschr physikal Chem ,' **22**, 505	V C ii.
25		Meyerhoffer	'Zeitschr physikal Chem ,' **22**, 619	II A
26		Lowenherz	'Zeitschr physikal Chem ,' **23**, 95	II A
27		Schiff	'Zeitschr physikal Chem ,' **23**, 355	V C i
27A		Noyes and Whitney	'Zeitschr physikal Chem ,' **23**, 639	II A , VII.
28		Bruner	'Zeitschr physikal Chem ,' **23**, 542	IV A
28A		Kuriloff	'Zeitschr physikal Chem ,' **23**, 547	II C
29		Roth .	'Zeitschr physikal Chem ,' **24**, 114	V C ii , VII
30		Hoitsema	'Zeitschr physikal Chem ,' **24**, 577	V C iii , VII
31		Gockel	'Chem. Centrb.,' **68** (ii.), 401 .	II A
32		Spezia .	'Zeitschr. f Kryst Min ,' **28**, 200	V B.
33		Fock	'Zeitschr f Kryst Min ,' **28**, 337	V C iii; VII
34		McIntosh	'J Phys Chem ,' **1**, 298	VII
35		Benedict	'J Phys Chem ,' **1**, 397	III B , V C. i.
36		McIntosh	'J Phys Chem ,' **1**, 474	VII.
37		Talmadge	'J Phys Chem ,' **1**, 547 .	II A ; III B , V C. i , VII , V C ii
38		Taylor	'J. Phys. Chem ,' **1**, 718	
39		Bohr	'Ann. Phys. Chem ,' (3), **62**, 644	V. A i.
40	1898	Herz	'Ber ,' **31**, 2669	II B. ; IV B. , VI.
41		Walker and Wood	'J Chem Soc ,' **73**, 618 . . .	III B ; IV B

No	Date	Author	Reference	Section
43	1898	Goldschmidt and Maarseveen	'Zeitschr. physikal Chem.,' **25**, 91	V A. ii; VII.
44		Fock . .	'Zeitschr physikal Chem,' **25**, 74	V C. iii; VI.; VII.
44A		Rothmund .	'Zeitschr physikal Chem,' **26**, 433, 460	VI.
45		Noyes and Woodworth	'Zeitschr physikal Chem,' **26**, 152	V C iii.
46		Goldschmidt and Cooper	'Zeitschr physikal Chem,' **26**, 711	IV A.
47		Bodlander	'Zeitschr physikal Chem,' **27**, 55	VII.
48		Noyes .	'Zeitschr physikal Chem,' **27**, 267	V C iii
49		Brown .	'J Phys. Chem,' **1**, 784	VII
50		Noyes and Whitney	'J Amer Chem. Soc,' **19**, 930 .	II A, VII.
51		Noyes and Schwarz	'J Amer Chem Soc,' **20**, 742	V C iii
52		Noyes and Chapin	'J Amer Chem Soc,' **20**, 751 .	V C. iii, VII
53		Dahms	'Ann. Phys Chem,' (3), **64**, 507.	V A i; VII.
54		Kaehler and Martini	'Zeitschr angew Chem,' **46**, 1049	II A.
55	1899	Pawlewski	'Ber,' **32**, 1040 .	II A
56		Aignan and Dugas	'Compt rend,' **129**, 643 . .	VI
57		Meyerhoffer & Saunders	'Zeitschr physikal Chem,' **28**, 466	V C iii
58		Estreicher	'Zeitschr physikal Chem,' **31**, 176	V A i
59		Arrhenius .	'Zeitschr physikal Chem,' **31**, 197	V C iii
60		Euler .	'Zeitschr physikal Chem,' **31**, 360	V C ii.
62		Franklin and Krauss	'Amer Chem. J,' **20**, 820 . .	III B; V.A. i.
64		Bruni . .	'Real Accad Lincei,' (5), **8**, (ii), 141	VI
65		Lotmar .	Inaug Diss Heidelberg .	V C i; VI.
66		Eidmann .	Inaug Diss Giessen . .	III B
67	1900	Mylius and Funk	'Ber,' **33**, 3686 . .	V A i.
68		Mylius and v Wrochem	'Ber,' **33**, 3689	V A. i.
69		Funk .	'Ber,' **33**, 3696 . . .	IV C; V A i
70		Newth .	'J Chem Soc,' **77**, 775	VI
71		Touren .	'Compt rend,' **130**, 908, 1252 .	V C iii
72		Rothmund	'Zeitschr physikal Chem,' **33**, 401	V C ii, VII.
73		Van der Lee.	'Zeitschr physikal Chem,' **33**, 622	V B, VI.
74		Braun . .	'Zeitschr physikal Chem,' **33**, 721	II C, V C i and ii.
75		Stortenbecker	'Zeitschr physikal Chem,' **34**, 108	VII.
76		Van Laar	'Zeitschr physikal Chem,' **35**, 11	V A ii
77		Bodländer	'Zeitschr physikal Chem,' **35**, 23	VII
78		Bruner and Tolloczko	'Zeitschr physikal Chem,' **35**, 283	VII.
79		Konowalow .	'J russ phys Chem Soc,' **31**, 910	V B
80		Konowalow	'J russ, phys Chem Soc,' **31**, 985	VII
81		Stolle . .	'Zeit Ver deutsch Zucher-Ind.,' p 321	V C ii.
82		Hopkins .	'Amer Chem J.,' **22**, 407 . .	II A
83		Cavalier and Prost	'Bull. Soc Chim.,' (3), **23**, 678 .	IV.C; V.A. i.

No	Date	Author	Reference	Section
84	1900	Deitz, Funk and others	'Wiss Abhand phys-tech. Reichsanstalt,' **3**, 425	V. A. i.
85		V. Ende	'Zeitschr anorg Chem,' **26**, 129.	V. C iii.
86		Winteler .	'Zeitschr f Elektrochem,' **7**, 360	V C iii.
87	1901	Winkler. .	'Ber,' **34**, 1408 . .	V A i.
88		Meusser .	'Ber,' **34**, 2432 .	IV C.; V.A i
89		Groschuff .	'Ber,' **34**, 3313 . .	V A. i, V C. iii
90		Mellor .	'J Chem Soc,' **79**, 225 .	V C ii.
91		Dawson and McCrae	'J Chem Soc,' **79**, 493 .	V C ii and iii, VII.
92		Dawson and McCrae	'J. Chem Soc,' **79**, 1072 . .	VI.
93		Massol and Maldès	'Compt rend,' **133**, 287 .	V C iii
94		Drucker	'Zeitschr physikal Chem,' **36**, 693	VII
95		Just .	'Zeitschr physikal Chem,' **37**, 342	III B
96		Hulett	'Zeitschr physikal Chem,' **37**, 385	IV A
97		Nernst	'Zeitschr physikal Chem,' **38**, 487	VII
98		Cameron	'J Phys Chem,' **5**, 556	V C iii, VII
99		Cameron and Seidell	'J Phys Chem,' **5**, 643 . .	V C iii.
100		Jaeger .	'Zeitschr anorg Chem,' **27**, 22.	V C iii
101		Wyrouboff	'Bull Soc Chim,' (3), **25**, 105	VII
102		Bruner and Tolloczko	'Zeitschr anorg Chem,' **28**, 314	VII.
103		Drucker .	'Zeitschr anorg Chem,' **28**, 361	V C iii
104		Drucker	'Zeitschr anorg Chem,' **29**, 459	VII
105		Tarugi and Checchi	'Gazzetta,' **31**, (ii), 417 . .	IV C
106		Rossi	'Gazzetta,' **31**, (ii), 502 .	IV C
107		Levi .	'Gazzetta,' 31, (ii), 513 .	V A i, V C i, VII
108		Holsboer .	'Proc K Akad Wetensch,' Amsterdam, **3**, 467	V A ii.
109		Cohen and Buchner	'Proc K Akad Wetensch,' Amsterdam, **3**, 561	VII
110		Enklaar	'Rec Trav Chim,' **20**, 183 .	V C iii, VII.
111		Campetti	'Atti Real Accad Lincei,' [5], **10**, (ii), 99	V.A ii
112		Locke	'Amer Chem J,' **26**, 332	IV C
113		Immerwahr	'Zeitschr f Elektrochem,' **7**, 477	II A
114		Marie	'Revue Gén Sci,' **12**, 686	IV A
115		Meyer	Inaug Diss Heidelberg	V C i
116	1902	Rimbach	'Ber,' **35**, 1298 .	V C iii
117		Meusser	'Ber,' **35**, 1414	IV B, V.A i
118		Lumsden	'J Chem Soc,' **81**, 350	IV B, V A. i.
119		Lumsden	'J Chem Soc,' **81**, 363	VII
120		Dawson and Grant	'J Chem Soc,' **81**, 512	VI
121		Dawson and Gawler	'J Chem Soc,' **81**, 528	V C ii.
122		Dawson .	'J Chem Soc,' **81**, 1086 .	VI
123		Findlay	'J Chem Soc,' **81**, 1217 . .	VII
124		Abegg and Riesenfeld	'Zeitschr physikal Chem.,' **40**, 84	V C iii.
125		Billitzer .	'Zeitschr physikal Chem,' **40**, 535	V C ii
126		Rothmund & Wilsmore	'Zeitschr physikal. Chem,' **40**, 611	V.C. iii, VII.
127		Findlay .	'Zeitschr. physikal. Chem.,' **41**, 28	VII.
128		Skirrow .	'Zeitschr. physikal. Chem,' **41**, 139	III.A.; V.C. i.

No	Date	Author	Reference	Section
129	1902	Fox	'Zeitschr physikal Chem,' **41**, 458	V c iii
130		Koppel	'Zeitschr physikal Chem.,' **42**, 1	V c iii.
131		Findlay	'Zeitschr physikal Chem,' **42**, 110	VII
132		Schick	'Zeitschr. physikal Chem,' **42**, 155	IV A
133		Muller and Kaufmann	'Zeitschr physikal Chem,' **42**, 497	V A. i
134		Myerhoffer	'Zeitschr physikal Chem.,' **42**, 501	VII
135		Ostwald	'Zeitschr physikal Chem,' **42**, 503	VII
136		Wildermann	'Zeitschr physikal Chem,' **42**, 481	VII
137		Cameron and Seidell	'J Phys Chem,' **6**, 50	V c iii
138		Kahlenberg & Schlundt	'J Phys Chem,' **6**, 447	III B
139		Seidell	'Amer Chem J,' **27**, 52	V c iii
140		Locke	'Amer Chem J,' **27**, 455	IV c
141		Hulett and Allen	'J Amer Chem Soc,' **24**, 667	V A i.
142		Noyes & Kohr	'J Amer Chem, Soc,' **24**, 1141	II A; V c iii, VII.
143		Speyers	'Amer J Sci,' [4], **14**, 293	III B
144		Findlay	'Proc Roy Soc,' **69**, 471	V c ii, VII
145		Rubenbauer	'Zeitschr anorg, Chem,' **30**, 331	V c iii
146		Bodländer & Storbeck	'Zeitschr anorg Chem,' **31**, 1	V c iii
147		Rabe	'Zeitschr anorg Chem,' **31**, 154	IV c
148		Finzi	'Gazzetta,' **32**, (ii), 324	V c iii
149		Schiavon	'Gazzetta,' **32**, (ii), 532	V c ii
150		Lumière and Seyewetz	'Bull. Soc. Chim,' (3), **27**, 1212	V c ii, VII
151		Pomeranz	'Monatsh,' **23**, 747	IV A
152	1903	Groschuff	'Ber,' **36**, 1783	IV c, V c iii
153		Euler	'Ber,' **36**, 2878	V A i, V c ii
154		Bruner	'Ber,' **36**, 3297	III B
155		Herz & Muhs	'Ber,' **36**, 3715	V c iii
156		Groschuff	'Ber,' **36**, 4351	V c iii
157		Walker and Fyffe	'J Chem Soc,' **83**, 173	IV B
158		Donnan and Burt	'J Chem Soc,' **83**, 335	V A i
160		Tutton	'J. Chem Soc,' **83**, 1049	IV c
161		Farmer	'J Chem Soc,' **83**, 1446	VI
162		Biltz	'Zeitschr physikal Chem,' **43**, 41	V c ii
163		Noyes and Sammet	'Zeitschr physikal Chem,' **43**, 513	V.A ii, VII
164		Thiel	'Zeitschr physikal Chem,' **43**, 641	VII
165		McLauchlan	'Zeitschr physikal Chem,' **44**, 600	II c., V c ii, VII
166		Riesenfeld	'Zeitschr physikal Chem,' **45**, 461	V c iii.
167		Abegg & Cox	'Zeitschr physikal Chem,' **46**, 1	II A
168		Mittasch	'Zeitschr physikal Chem,' **46**, 37	III B.
169		Bottger	'Zeitschr physikal Chem,' **46**, 521	II A., IV A
170		Cameron and Breazeale	'J. Phys. Chem,' **7**, 571	V.c iii
171		Cameron and Seidell	'J. Phys Chem,' **7**, 578	V c. iii.
172		Foote	'Amer Chem J,' **30**, 330	V c iii.
173		Foote	'Amer Chem J,' **30**, 339	V c iii.
174		Horn and Wagener	'Amer, Chem J,' **30**, 344	V A. i
175		Lichty	'J. Amer. Chem. Soc.,' **25**, 469	V.A. i.

No	Date	Author	Reference	Section
176	1903	Bogdan	'Ann. Sci Univ Jassy,' **2**, 95	V c i; ii and iii, VII
177		Bougault	'J Pharm Chim,' [6], **18**, 116	V c ii.
178		Lowry .	'Proc Chem Soc,' [1903], 156	IV B
179		Bullerdieck	Inaug Diss Gottingen	V c iii
180		Smits .	'Proc K Akad Wetensch,' Amsterdam, **6**, 171	III A
181		Cassuto	'Nuovo Cim,' [5], **6**, 5	II c, V A i, V B
182		Centnerszwer & Teletoff	'Zeitschr f Elektrochem,' **9**, 799	III A, V A i
183		Herz	'Zeitschr anorg Chem,' **34**, 205	V c iii
184		McCrae and Wilson	'Zeitschr anorg Chem,' **35**, 11	VI
185		Bruner and Tolloczko	'Zeitschr anorg Chem.,' **35**, 23	VII
186		Goldschmidt	'Zeitschr anorg Chem,' **36**, 88	V c ii
187		Vaubel	'J prkt Chem,' (2), **67**, 473	VI, VII
188	1904	Groschuff	'Ber,' **37**, 1486	V c iii
189		Herz and Fischer	'Ber,' **37**, 4746	VI
190		Steele and Johnson	'J Chem Soc,' **85**, 113	V A i
191		Dawson and Goodson	'J Chem Soc.,' **85**, 796	V c ii
192		Clowes and Briggs	'J Soc Chem Ind,' **23**, 358	V c ii
193		Stanley	'Chem News,' **89**, 193	IV c, V A i
194		Hudson	'Zeitschr physikal Chem,' **47**, 113	VI
195		Hulett	'Zeitschr physikal Chem,' **47**, 357	IV A
196		Bresler	'Zeitschr physikal Chem,' **47**, 611	V A i
197		Kohlrausch	'Zeitschr physikal Chem,' **47**, 625	IV A
198		Knopp	'Zeitschr physikal Chem,' **48**, 97	II c, V c ii
199		Gardner and Gerassimoff	'Zeitschr physikal Chem,' **48**, 359	VII
200		Geffcken	'Zeitschr physikal Chem,' **49**, 257	V c ii
201		Euler	'Zeitschr physikal Chem,' **49**, 303	V c ii
202		Hulett .	'Zeitschr physikal Chem,' **49**, 483	V c iii
203		Kohlrausch	'Zeitschr physikal Chem,' **50**, 355	V A i
204		Cameron and Breazeale	'J Phys Chem,' **8**, 335	V c iii
205		Seidell and Smith	'J phys Chem.,' **8**, 493	V c iii
206		Jones and Getmann	'Amer Chem J,' **32**, 308, 338	VII
207		Hudson	'J Amer Chem Soc,' **26**, 1065	V A i
208		Vèzes and Mouline	'Bull. Soc Chim,' (3), **31**, 1043	VI
209		Cantoni and Zachoder	'Bull. Soc Chim,' (3), **31**, 1121 .	IV c, V A i
210		Euler . .	'Arkiv Kem Min Geol,' **1**, 133	V c ii.
211		Euler .	'Arkiv Kem. Min Geol,' **1**, 143.	V c ii
212		Cantoni	'Ann. Chim. Anal,' (3), **9**, 81	II A
213		Earl of Berkeley	'Phil Trans,' **203**, A, 189 .	II A., V A i.
214		Richardson .	'Phil Mag,' (6), **7**, 266 .	V A i and ii, VII
215		Auerbach .	'Zeitschr f Elektrochem,' **10**, 161	V c iii.
216		Herz & Knoch	'Zeitschr anorg Chem,' **41**, 315	V c ii.
217		Koppel . .	'Zeitschr anorg Chem,' **41**, 377.	V A i.

No	Date	Author	Reference	Section
218	1904	Centnerszwer & Teletoff	'J russ phys Chem Soc,' **36**, 62	V.A. i.
219		Schurr .	'J Chim Phys,' **2**, 245 . .	VII
219A		Raikov .	'Chem Zeitung,' No **103**, 1247	II C
220	1905	Herz and Fischer	'Ber,' **38**, 1138	VI
221		Rimbach and Grewe	'Ber,' **38**, 1553, 1564 . . .	V.C. iii
222		Dolinski	'Ber,' **38**, 1835	IV.B
223		Naumann and Rucker	'Ber,' **38**, 2292 . .	V C iii.
224		Abegg & Pick	'Ber,' **38**, 2571 . . .	V C iii
225		Moir . .	'Proc Chem Soc,' **21**, 310 . .	III B
226		Philip . .	'J Chem Soc,' **87**, 987 . .	V C iii.
227		Worley .	'J Chem Soc,' **87**, 1107	V C ii.
228		Lowry .	'Trans Faraday Soc,' **1**, 197 .	VII.
229		Dreaper	'Chem News,' **92**, 229 .	VII
230		Hoffmann & Langbeck	'Zeitschr physikal Chem,' **51**, 385	V C ii and iii; VII.
230A		Van't Hoff	Braunschweig, Pt I, 1905, II, 1909	V C iii
231		Jones and Bassett	'Zeitschr physikal Chem,' **52**, 231	VII
232		Koppel	'Zeitschr physikal Chem,' **52**, 385	V C iii
233		Aten	'Zeitschr physikal Chem,' **54**, 121	III B, V A i
234		Cameron and Browne	'J Phys, Chem,' **9**, 210	V C iii
235		Holty . .	'J Phys Chem,' **9**, 764	IV A
236		Richards and Wells	'J Amer Chem Soc,' **27**, 459	IV A.
237		Lattey	'Phil Mag,' (6), **10**, 397	VI
238		Bogwski	'J russ phys Chem Soc,' **37**, 92	V A i.
239		Rogowicz	'Zeit Ver Rubenzucker-Ind,' p 596, 938	V C ii
240		Roozeboom	'Proc Sci Akad Wetensch,' **8**, 66	V C iii
241		Cantoni and Zachoder	'Bull Soc Chim,' (3), **33**, 747	IV C, V A. i
242		Stromholm .	'Arkiv Kem Min Geol,' **2** [ii], (7), i	V C i.
243		Fleckenstein	'Physikal Zeitung,' **6**, 419 . .	II A, III B, V C ii
244		Kuster and Heberlein	'Zeitschr anorg Chem,' **43**, 53	V A i, V C ii
245		Geffcken .	'Zeitschr anorg Chem,' **43**, 197	V C iii
246		Muller	'Zeitschr anorg Chem,' **43**, 320	III B
247		Kuster and Dahmer	'Zeitschr anorg Chem,' **43**, 348	V C iii
248		Schroder .	'Zeitschr anorg Chem.,' **44**, 1 .	III B, IV.C.
249		Wolff . .	'Zeitschr anorg, Chem,' **45**, 89 .	IV B
250		Christomanos	'Zeitschr anorg Chem,' **45**, 132.	V A i
251		Herz & Knoch	'Zeitschr anorg Chem,' **45**, 262.	V C ii
252		Herz & Knoch	'Zeitschr anorg Chem,' **46**, 193	V C ii.
253		Bruner and Tolloczko	'J Chim Phys,' **3**, 625 .	VII.
253A		Christoff .	'Zeitschr physikal Chem,' **53**, 321	II C.
254		Schiller . .	'Zeitschr. physikal Chem,' **54**, 455	VII
255		Buchner .	'Zeitschr physikal Chem,' **54**, 665	III B.
256		Van Laar .	'Zeitschr. physikal. Chem.,' **54**, 750	VII.
257	1906	Ruff & Geisel	'Ber.,' **39**, 828	III B
258		Fischer . .	'Ber.,' **39**, 4144	V C. iii; VII
259		Hartley and Thomas	'J. Chem. Soc,' **89**, 1013 . .	II A.

No	Date	Author	Reference	Section
260	1906	Lowry . .	'J Chem Soc,' **89**, 1033 . .	IV.B ; V.C. II.
261		Steele, McIntosh and Archibald	'Phil Trans,' A **205**, 99 . .	III.B.
262		Winkler .	'Zeitschr physikal Chem,' **55**, 344	III A., IV.C. ; V A I, VII
263		Rex .	'Zeitschr physikal Chem,' **55**, 358	II B, V.A. I, VII
264		Levin	'Zeitschr physikal Chem,' **55**, 513	VII
265		Christoff	'Zeitschr physikal Chem,' **55**, 622	III A.
266		Walden	'Zeitschr physikal Chem.,' **55**, 683	III B, IV.B ; IV C, V A. I, VII
267		Bottger	'Zeitschr physikal Chem,' **56**, 83	IV B, V A I
268		Trautz and Anschutz	'Zeitschr physikal Chem,' **56**, 236	II A, IV.C.
269		Riedel	'Zeitschr physikal Chem,' **56**, 243	V C II ; VI.
270		Buchner	'Zeitschr physikal Chem,' **56**, 257	VI
270A		Hufner	'Zeitschr physikal Chem,' **57**, 611	II C
271		Trevor	'J Phys Chem,' **10**, 99	VII
272		Bell & Taber	'J Phys Chem,' **10**, 119	V C III
273		Cameron and Bell	'J Phys Chem,' **10**, 210 .	V C III
274		Taber	'J Phys Chem,' **10**, 626 .	V C III
275		Foote & Levy	'Amer Chem J,' **35**, 236 .	V C III.
276		Foote and Menge	'Amer Chem J,' **35**, 432 .	IV B.
277		Gibbs .	'J Amer Chem Soc,' **28**, 1395 .	III B
278		Barlow	'J Amer Chem Soc,' **28**, 1446 .	V C III.
279		Dolezalek and Finckh	'Zeitschr anorg Chem,' **51**, 320.	V.C III.
280		Schreinemakers and Dorp	'Chem Centrb,' [II], 1235 .	V C. II.
281		Schreinemakers and Bornwater	'Chem Centrb,' [II], 1306 .	V C II
282		Longinescu	'Chem Centrb,' [II], 1374 . .	VII.
283		Smirnoff .	'J russ phys Chem Soc,' **38**, (I), 5	IV C, V C II VII
284		Veimarn .	'J russ phys Chem Soc,' **38**, (I), 228	II A
285		Thiele and Calberla	'Zeitschr angew Chem,' **19**, 1263	II A
286		Galeotti	'Zeitschr. physiol Chem,' **48**, 473	V C II
287		Cantoni and Basadonna	'Bull Soc Chim,' (3), **35**, 727 .	IV C, V A. I
288		Pajetta . .	'Gazzetta,' **36**, (3), 67 .	IV C, V A. I
288A		Hudson .	'Physical Review,' **23**, 370	V C II
289	1907	Biltz . .	'Zeitschr physikal Chem,' **58**, 288	II A.
290		Weigel . .	'Zeitschr physikal Chem,' **58**, 293	IV A
291		Smirnoff .	'Zeitschr physikal Chem,' **58**, 373	VI
292		Van Laar .	'Zeitschr physikal Chem,' **59**, 212	III B
293		Hufner .	'Zeitschr. physikal Chem,' **59**, 416	V C II
294		Ritzel .	'Zeitschr physikal Chem,' **60**, 319	III A
295		Centnerszwer & Kalnin	'Zeitschr physikal Chem,' **60**, 441	VI.
296		Shinn . .	'J Phys. Chem,' **11**, 537 . .	III.B ; VII.
297		Cameron and Robinson	'J. Phys. Chem.,' **11**, 577 . .	V.C. II.

No	Date	Author	Reference	Section
297A	1907	Bell and Taber	'J Phys. Chem ,' 11, 637	V c iii
298		Parsons	'J Phys Chem ,' 11, 659	VII
299		Bingham	'Amer Chem J ,' 37, 549	VI.
300		Bingham	'Amer Chem J ,' 38, 91	VI , VII
301		Seidell	'J Amer Chem Soc ,' 29, 1088	V c ii
302		Emerson	'J Amer Chem Soc ,' 29, 1750	II A
303		Krauss	'J Amer Chem Soc ,' 29, 1557	III B
304		Magie .	'Proc Amer Phil. Soc ,' 46, 138	VII
305		Armstrong and Eyre	'Proc Roy Soc ,' A , 79, 564 .	V c ii, V c iii, VII
306		Jones	'Proc Camb Phil Soc ,' 14, 27	III B , IV B
307		Philip	'J Chem Soc ,' 91, 711	V c i , V c ii
307A		Philip	'Trans Faraday Soc ,' 3, 140	V c ii, V c iii
308		Menschutkin	'Zeitschr anorg Chem ,' 52, 152	IV c , V A i
309		Herz and Anders	'Zeitschr anorg Chem ,' 52, 164	V c ii
310		Duleski	'Zeitschr anorg Chem ,' 53, 327	V c ii
311		Herz and Anders	'Zeitschr anorg Chem ,' 55, 271	V c ii
312		Bruner and Tolloczko	'Zeitschr anorg Chem ,' 56, 58	VII
313		Osaka	'Mem Coll Sci Eng Kyōto ,' 1, 265	II A
314		Dubroca	'J Chim Phys ,' 5, 463	II B , VI
315		Magri	'Atti R Accad Lincei,' (5), 16, (i), 518	III B
316		Rogojawlenski and others	'Schrift Dorpat Natur, f Ges ,' 15, 216	IV B
317		Smirnoff	'J russ phys Chem Soc ,' 39, (i), 78	V c ii , VII
318		Pleissner	'Chem Centrb ,' (ii), 1055	V c , iii
319		Ostromysslensky	'J prakt Chem ,' (2), 76, 264	VII
320	1908	Spencer and Le Pla	'J Chem Soc ,' 93, 858	V c iii
321		Flaschner and MacEwen	'J Chem Soc ,' 93, 1000	VI
322		Buttle and Hewitt	'J Chem Soc ,' 93, 1405	V c iii
323		Moody and Leyson	'J Chem Soc ,' 93, 1767	V A i
324		Gaillard	'Compt rend ,' 146, 1020	II A
325		Baubigny	'Compt rend ,' 146, 1263	V A i , V c iii
326		Walden	'Zeitschr physikal Chem ,' 61, 633	III B
327		Flaschner	'Zeitschr physikal Chem ,' 62, 493	VI
328		Usher	'Zeitschr physikal Chem ,' 62, 622	V c ii , V c iii
329		Kohlrausch	'Zeitschr physikal Chem ,' 64, 129	II A , V A i
330		Cameron and Patten	'J Phys Chem ,' 11, 581 .	VI.
331		Hill	'J Amer Chem Soc ,' 30, 68, 303	II A
332		Archibald and others	'J Amer Chem Soc ,' 30, 747 .	V c iii
333		Stieglitz	'J Amer. Chem Soc ,' 30, 946	V c iii
334		Armstrong	Proc Roy. Soc ,' A , 81, 80	VII
335		Menschutkin	'J russ phys Chem Soc ,' 40, 1415	III B
336		Herz & Kuhn	'Zeitschr anorg Chem ,' 58, 159	V c ii
337		Herz & Kuhn	'Zeitschr anorg Chem ,' 60, 152	III B., V.c ii
338		Osaka	'Mem.Coll Sci Eng Kyōto ,' 1, 290	II A
339		Kofler	'Physikal. Zeit.,' 9. 6 . .	V c. i ; V c. ii

No	Date	Author	Reference	Section
340	1908	Galeotti and Giampalmo	'Zeit Chem Ind. Kolloide,' 3, 118	V c i
341		Findlay	'Zeit Chem Ind Kolloide,' 3, 169	V c ii
342		Schroder	'J prakt Chem,' (2), 77, 267	V c ii
343		Rothmund	'Zeitschr Elektrochem,' 14, 532	V c ii, VII
343A		Hudson	'Zeitschr Elektrochem,' 14, 821	V c ii
344		Kernot and Agostine	'Gazzetta,' 38, (i), 532	V c iii
345		Hanser & Wirth	'Zeitschr anal Chem,' 47, 389	V c iii
346		Gudzent	'Zeitschr. physiol Chem,' 56, 150	IV B
347		Free	'J Amer Chem Soc,' 30, 1366	V c iii
348	1909	Traube	'Ber,' 42, 86	VII
349		Fuhner	'Ber,' 42, 887	V c i
350		Traube	'Ber,' 42, 2185	V c ii
351		Stolzenberg	'Ber,' 42, 4322	II A
352		Duclaux	'Compt rend,' 148, 295	IV A
353		Philip and Garner	'J Chem Soc,' 95, 1466	V c iii
354		Rimbach and Schubert	'Zeitschr physikal Chem,' 67, 183	IV c
355		Cohen and Sinnige	'Zeitschr physikal Chem,' 67, 432	II A, V B
356		Cohen and Sinnige	'Zeitschr physikal Chem,' 69, 102	II A, V B
357		Rothmund	'Zeitschr physikal Chem,' 69, 523	V c ii, VII
358		Jones	'Amer Chem J,' 41, 19	VII
359		Getman and Wilson	'Amer Chem J,' 41, 344	II A
360		Hudson	'J Amer Chem Soc,' 31, 63	V c ii, VII
361		Hill and Simmons	'J Amer Chem Soc,' 31, 821	V c iii
362		Schroder	'Zeitschr anal Chem,' 48, 349, 351	II A
363		Kohn	'Zeitschr anorg Chem, 63, 337	V c iii
364		Gillet	'Bull Soc, Chim,' 23, 119	VII
365		Timmermans	'Bull Soc Chim,' 23, 129	V B, VI, VII
366		Limbosch	'Bull, Soc Chim Belg,' 23, 179	V c ii, VI
367		Pauli & Samec	'Biochem Zeitschr,' 17, 235	V c ii
368	1910	Sieverts and Krumbhaar	'Ber,' 43, 893	III A, III B, V B
368A		Usher	'J Chem Soc,' 97, 66	II c, V c ii, VII
369		Findlay and Creighton	'J Chem Soc,' 97, 536	III A, V B, IV c i
370		Tyrer	'J Chem Soc,' 97, 621	III A, V A i, VII
371		Homfray	'J Chem Soc,' 97, 1669	III A
372		Tyrer	'J Chem Soc,' 97, 1778	V c i, VII
373		Barre	'Compt rend,' 150, 1321	V c iii
374		Rindell	'Zeitschr physikal Chem,' 70, 452	V c iii
375		Bohr	'Zeitschr physikal Chem,' 71, 47	V c ii
376		Dolezalek	'Zeitschr physikal Chem,' 71, 191	III B, IV A
377		Wagner	'Zeitschr physikal Chem,' 71, 401	IV A
378		Centnerszwer	'Zeitschr physikal Chem,' 72, 431	III A, V A i
379		Fontein	'Zeitschr physikal Chem,' 73, 212	V c i
380		Landau	'Zeitschr physikal Chem,' 73, 200	VI
381		Van Dorp	'Zeitschr physikal Chem,' 73, 284, 289	V c iii
382		Drucker and Moles	'Zeitschr physikal Chem,' 75, 405	II c, V c i and ii, V B.
383		Traube	'J phys Chem,' 14, 452, 471	VII

No	Date	Author	Reference	Section
384	1910	Melcher .	'J Amer Chem Soc,' **32**, 50 .	V A. i.
385		Washburn	'J Amer, Chem Soc,' **32**, 467	V C iii
386		Hill .	'J Amer Chem Soc,' **32**, 1186	V C iii, VII
387		Parsons and Perkins	'J Amer Chem Soc,' **32**, 1383 and 1387	V C iii
388		Antropoff .	'Proc Roy Soc,' A **83**, 474 .	IV C., V A. i
389		Armstrong and Eyre	'Proc Roy Soc,' A **84**, 123 .	V C ii, V C iii, VII.
390		Herz .	'Zeitschr anorg. Chem.,' **65**, 341.	V C. iii.
391		Herz. .	'Zeitschr anorg Chem,' **66**, 93	V C iii.
392		Herz	'Zeitschr anorg. Chem,' **67**, 365	V C. iii.
393		D'Ans and Schreiner	'Zeitschr anorg Chem,' **67**, 437.	V C iii.
394		Beck and Steigmuller	'Arb K Gesundh-Amt,' **34**, 446	V C iii.
395		Uyeda .	'Mem Coll Sci Eng Kyōto, **2**, 245	V C iii.
396		Herz and Kurzer	'Zeitschr f Elektrochem,' **16**, 240, 869	VI.
397		Moles	'Anal Fis Quim,' **9**, 79	II C
398		Cohen, Inouye & Euwen	'Zeitschr physikal Chem,' **75**, 257	V B
399	1911	Jones . .	'J Chem Soc,' **99**, 392 . .	II C
400		Sidgwick, Pickford & Wilsdon	'J Chem Soc,' **99**, 1122	V C ii; VI
401		Masson . .	'J. Chem. Soc,' **99**, 1132	V C iii
402		Sieverts .	'Zeitschr physikal Chem,' **77**, 591	III A; V A. i; V B
403		Barre . .	'Compt rend,' **151**, 871 . .	V C iii
404		Bell & Field	'J Amer Chem Soc,' **33**, 940 .	VI
405		Noyes & Bray	'J Amer Chem Soc,' **33**, 1643 .	V C iii; VII
406		Noyes, Boggs, etc	'J Amer Chem Soc,' **33**, 1650	V C iii; VII
407		Bray and Winninghoff	'J Amer Chem Soc,' **33**, 1663 .	V C iii; VII
408		Bray	'J Amer Chem Soc,' **33**, 1673	V C iii, VII
409		Harkins.	'J Amer Chem Soc,' **33**, 1807 .	V C iii; VII
410		Harkins and Winninghoff	'J Amer Chem Soc,' **33**, 1827 .	V C iii.
411		Harkins	'J Amer Chem Soc,' **33**, 1836	V C iii.
412		Forbes . .	'J Amer Chem Soc,' **33**, 1937	V C iii
413		Kendall	'Proc Roy Soc,' A. **85**, 200	V C iii, VII
415		Gibson and Denison	'Proc Roy Soc Edinb,' **30**, 562	V C iii; VII
416		Prud'homme	'J Chim Phys,' **9**, 517 .	II A
417		Herz . .	'Zeitschr anorg Chem,' **70**, 70 .	V C iii
418		Herz.	'Zeitschr anorg Chem,' **73**, 274	V C iii
419		Groschuff	'Zeitschr f Elektrochem,' **17**, 348	II B
420		Ramstedt	'Le Radium,' **8**, 253	III B
421		Nasini and Ageno	'Gazzetta,' **41**, (i), 131 . .	V A i.
422		Brichaux .	'Bull Soc Chim Belg,' **25**, 145	V A i.
423		Kolossovsky.	'Bull Soc Chim Belg,' **25**, 183 .	VI.

IX.—*Authors' Index to Parts I. and II.*

Authors	Reference Numbers	Authors	Reference Numbers
Fock	Part I, 206, Part II, 33, 44a	Gudzent	Part II, 346
Fontein	Part II, 379	Guthrie	Part I, 105, 106, 114
Foote	Part II, 172, 173	Handl	Part I, 50
Foote and Levy	Part II, 275	Hannay and Hogarth	Part I, 75, 80
Foote and Menge	Part II, 276	Harkins	Part II, 409, 411
Forbes	Part II, 412	Harkins and Winninghoff	Part II, 410
Fox	Part II, 129	Hartley and Thomas	Part II, 259
Franklin and Krauss	Part II, 62	Hauer, v	Part I, 41, 44
Free	Part II, 347	Hauser and Wirth	Part II, 345
Fuhner	Part II, 349	Hecht	Part I, 92
Funk	Part II, 69	Heidenhain and Meyer	Part I, 34
Funk and Mylius	Part II, 15, 16, 67	Henrich	Part I, 193
Funk, Dietz, &c	Part II, 84	Henry	Part I, 3, 111
Fyffe and Walker	Part II, 157	Herberlein and Kuster	Part II, 244
Gaillard	Part II, 324	Herz	Part II, 40, 183, 390, 391, 392, 417, 418
Galeotti	Part II, 286	Herz and Anders	Part II, 309
Galeotti and Giampalmo	Part II, 340	Herz and Fischer	Part II, 189, 220
Gardner and Gerassimoff	Part II, 199	Herz and Knoch	Part II, 216, 251, 252
Garner and Philip	Part II, 353	Herz and Kuhn	Part II, 336, 337
Gassendi	Part I, 1	Herz and Kurzer	Part II, 396
Gawler and Dawson	Part II, 121	Herz and Muhs	Part II, 155
Gay-Lussac	Part I, 5, 6, 7, 8, 13	Hewitt and Buttle	Part II, 322
Geffcken	Part II, 200, 245	Hill	Part II, 331, 386
Geisel and Ruff	Part II, 257	Hill and Simmons	Part II, 361
Gerardin	Part I, 39	Hoff van't	Part II, 230a
Gerassimoff and Gardner	Part II, 199	Hoffmann and Langbeck	Part II, 230
Getmann and Jones	Part II, 206	Hogarth and Hannay	Part I, 75, 80
Getmann and Wilson	Part II, 359	Hoitsema	Part II, 30
Giampalmo and Galeotti	Part II, 340	Holleman and Antusch	Part I, 226
Gibbs	Part II, 277	Holsboer	Part II, 108
Gibson and Denison	Part II, 415	Holst and Prytz	Part I, 231
Gillett	Part II, 364	Holtz	Part II, 235
Giraud	Part I, 116	Homfray	Part II, 371
Gniewosz and Walfisz	Part I, 130	Hopkins	Part II, 82
Gockel	Part II, 31	Horn and Wagener	Part II, 174
Goldschmidt	Part I, 236, Part II, 168	Hudson	Part II, 194, 207, 243a, 288a, 360
Goldschmidt and Cooper	Part II, 46	Hufner	Part I, 69, Part II, 270a, 293
Goldschmidt and Maarseveen	Part II, 43	Hulett	Part II, 96, 195, 202
Goodson and Dawson	Part II, 191	Hulett and Allen	Part II, 141
Goodwin	Part I, 93, 212	Immerwahr	Part II, 113
Gordon	Part I, 239	Inouye, Cohen and Euwen	Part II, 398
Grant and Dawson	Part II, 120		
Grewe and Rimbach	Part II, 221		
Groschuff	Part II, 89, 152, 156, 188, 419		

Authors	Reference Numbers
Jaeger	Part II., 100
Jahn	Part I., 240
Jakowkin	Part I., 243, Part II., 4
Jeannel	Part I., 122
Johnson and Steele	Part II., 190
Jones, H. C.	Part II., 358
Jones, H. O.	Part II., 306
Jones, W. J.	Part II., 399
Jones and Bassett	Part II., 231
Jones and Getmann	Part II., 206
Jungfleisch and Berthelot	Part I., 49
Just	Part II., 95
Kaehler and Martini	Part II., 54
Kahlenberg and Schlundt	Part II., 138
Kalnin and Centnerszwer	Part II., 295
Karsten	Part I., 11
Kaufmann and Muller	Part II., 133
Keightley and Page	Part I., 47
Kendall	Part II., 413
Kernot and Agostine	Part II., 344
Khanikof and Louguinine	Part I., 42
Kipping and Pope	Part II., 19
Klepl	Part I., 89
Knoch and Herz	Part II., 216, 251, 252
Knopp	Part II., 198
Koehler	Part I., 79
Kofler	Part II., 339
Kohlrausch	Part II., 197, 203, 329
Kohlrausch and Rose	Part I., 204
Kohn	Part II., 363
Kohr and Noyes	Part II., 142
Kolossovsky	Part II., 423
Konowalow	Part I., 87, 225, Part II., 79, 80
Kopp	Part I., 10
Koppel	Part II., 130, 217, 232
Kosman	Part I., 135
Krauss	Part II., 303
Krauss and Franklin	Part II., 62
Kremers	Part I., 17, 21, 22
Krumbhaar and Sieverts	Part II., 368
Kuhn and Herz	Part II., 336, 337
Kuntze and Muthmann	Part I., 217
Kuriloff	Part II., 28a
Kurnakoff	Part I., 194
Kurzer and Herz	Part II., 396
Küster	Part I., 183a, 208, 208a; Part II., 12
Kuster and Dahmer	Part II., 247
Kuster and Herberlein	Part II., 244
Laar, van	Part I., 224, 242; Part II., 76, 256, 292
Lajoux	Part I., 62
Landau	Part II., 380
Langbeck and Hoffmann	Part II., 230
Lattey	Part II., 237
Le Blanc and Noyes	Part I., 165
Le Chatelier	Part I., 112, 129, 146, 221, Part II., 3, 8, 23
Lee, van der	Part II., 73
Leidie	Part I., 90
Lenier	Part I., 82
Le Pla and Spencer	Part II., 320
Levi	Part II., 107
Levin	Part II., 264
Levy and Foote	Part II., 275
Leyson and Moody	Part II., 323
Lichty	Part II., 175
Lieben	Part I., 220
Liebig	Part I., 15
Limbosch	Part II., 366
Limpricht	Part I., 55
Linebarger	Part I., 211, 237
Lobry de Bruyn	Part I., 199
Locke	Part II., 112, 140
Longinescu	Part II., 282
Lotmar	Part II., 65
Louguinine and Khanikof	Part I., 42
Lowenherz	Part I., 241, Part II., 26
Lowry	Part II., 178, 228, 260
Lubarsch	Part I., 148
Lumière, A. and L., and Seyewetz	Part II., 150
Lumsden	Part II., 118, 119
Maarseveen and Goldschmidt	Part II., 43
MacEwen and Flaschner	Part II., 321
Mackenzie	Part I., 66
Magie	Part II., 304
Magri	Part II., 315
Mailfert, L'Abbé	Part I., 227
Maldès and Massol	Part II., 93
Marchand	Part I., 14
Marie	Part II., 114

Authors	Reference Numbers
Raoult	Part I, 53
Raupenstrauch	Part I., 113
Regnault	Part I, 76
Rex	Part II, 263
Richards and Wells	Part II, 236
Richardson	Part II, 214
Riecke	Part I, 174
Riecker and Van Deventer	Part I., 160
Riedel	Part II, 269
Riesenfeld	Part II, 166
Riesenfeld and Abegg	Part II, 124
Rimbach	Part II, 17, 116
Rimbach and Grewe	Part II, 221
Rimbach and Schubert	Part II, 345
Rindell	Part II, 374
Ritzel	Part II, 296
Robinet	Part I, 35
Robinson and Cameron	Part II, 297
Rodger and Thorp	Part I, 216
Roelofsen	Part I, 213
Rogojawlenski and others	Part II, 316
Rogowicz	Part II, 239
Roozeboom	Part I, 110, 115, 138, 140, 141, 159, 182, 183, 198, Part II, 240
Roscoe	Part I, 25
Roscoe and Dittmar	Part I, 29
Rose and Kohlrausch	Part I, 204
Rossi	Part II, 106
Roth	Part II, 29
Rothmund	Part II, 44, 72 343, 357
Rothmund and Wilsmore	Part II, 126
Rubenbauer	Part II, 145
Rucker and Naumann	Part II, 223
Rudorff	Part I, 52, 117
Ruff and Giesel	Part II, 257
Ruyssen and Varenne	Part I., 84
Samec and Pauli	Part II, 367
Sammet and Noyes	Part II, 163
Saunders and Meyerhoffer	Part II, 57
Schiavon	Part II, 149
Schick	Part II, 132
Schiff	Part I., 32, Part II, 27
Schiller	Part II, 254
Schloessing	Part I, 51
Schlundt and Kahlenberg	Part II, 138
Schonach	Part I, 77
Schreiner and D'Ans	Part II, 393
Schreinemakers and Bornwater	Part II, 281
Schreinemakers and Dorp	Part II, 280
Schroder	Part I, 131, 202, Part II, 248, 342, 362
Schubert and Rimbach	Part II, 354
Schuncke	Part I, 74, 218
Schurr	Part II, 219
Schwarz and Noyes	Part II, 51
Sedlitzky	Part I, 132
Seidell	Part II, 139, 301
Seidell and Cameron	Part II, 99, 171
Seidell and Smith	Part II, 205
Setschenoff	Part I, 46a, 61, 65, 120, 125, 142, 184
Seyewetz and Lumiere	Part II, 150
Shenstone and Tilden	Part I, 99, 103
Shinn	Part II, 296
Sidgwick, Pickford and Wilsdon	Part II, 400
Sieverts	Part II, 402
Sieverts and Krumbhaar	Part II, 368
Silbermann and Favre	Part I, 16
Simmons and Hill	Part II, 361
Sims	Part I, 31, 45
Sinnige and Cohen	Part II, 355, 356
Skirrow	Part II, 128
Smirnoff	Part II, 283, 291, 317
Smith and Seidell	Part II, 205
Smits	Part II, 180
Sondén and Pettersson	Part I, 154
Sorby	Part I, 33
Spencer and Le Pla	Part II, 320
Speyers	Part II, 11, 143
Spezia	Part II, 32
Stackelburg, v	Part II, 5
Stadt, Van d., and Van Deventer	Part I, 187
Stanley	Part II, 193
Steele and Johnson	Part II, 190
Steele, McIntosh and Archibald	Part II, 261
Stegmuller and Beck	Part II., 394
Steiner	Part I, 219
Stieglitz	Part II, 333
Stolle	Part II, 81

INDEX.

References to reports and papers printed in extenso *are given in Italics*
*An asterisk * indicates that the title only of the communication is given*
The mark † indicates the same, but that a reference is given to the Journal or Newspaper where the paper is published in extenso

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Life Members (since 1845), and all Annual Members who have not intermitted their Subscription, receive gratis all Reports published after the date of their Membership Any other volume they require may be obtained on application at the Office of the Association, Burlington House, Piccadilly, London, W, at the following prices: Reports for 1831 to 1874 (*of which more than 15 copies remain*), at 2*s* 6*d* per volume; after that date, at two-thirds of the Publication Price A few sets, from 1831 to 1874 inclusive, may also be obtained at £10 per set

Associates for the Meeting in 1912 may obtain the Volume for the Year at two-thirds of the Publication Price

REPORT OF THE EIGHTY-FIRST MEETING, at Portsmouth, August 30, 1911, *Published at* £1 4*s*

CONTENTS.

Publications on Sale at the Office of the Association.

Lithographed Signatures of the Members who met at Cambridge in 1833, with the Proceedings of the Public Meetings, 4to, 4*s*

Index to the Reports, 1831–1860, 12*s* (carriage included)

Index to the Reports, 1861–1890, 15*s* (carriage, 4*d*)

Lalande's Catalogue of Stars, £1 1*s*

Rules of Zoological Nomenclature, 1*s*

On the Regulation of Wages by means of Lists in the Cotton Industry —Spinning, 2*s* , Weaving, 1*s*

Report on the best means for promoting Scientific Education in Schools, 1867, 6*d*

Report on Electrolysis, 1886, 1*s* ; 1887, 6*d* ; 1888, 6*d*

Second Report on the present Methods of teaching Chemistry, 1889, 6*d*

Fifth to Twelfth Reports on the North-Western Tribes of Canada, 1889, 1*s* , 1890, 2*s* 6*d* , 1891, 1*s* , 1892, 1*s*., 1894, 6*d* , 1895, 1*s* 6*d* , 1896, 6*d* , 1898, 1*s* 6*d*

Discussion on the Theory of Solution, 1890, 6*d*

Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements, 1892, 6*d* , 1893, 6*d* , 1894, 1*s* , 1895, 6*d*.; 1899, 6*d* , 1903, 6*d* , 1904, 6*d* , 1905, 6*d* , 1906, 6*d* , 1907, 6*d* , 1908, 6*d* , 1909, 3*d*

Second Report on the Development of Graphic Methods in Mechanical Science, 1892, 1*s*

Report on the Ethnographical Survey of the United Kingdom, 1893, 6*d* , 1894, 6*d*.

The Action of Magnetism on Light, by J Larmor, F R S , 1893, 1*s*

Report on the Character of the High-level Shell-bearing Deposits at Clava, Chapelhall, and other Localities, 1893, 6*d*

Report on the Present State of our Knowledge of Electrolysis and Electrochemistry, 1893, 6*d*

Report on the Present State of our Knowledge of Thermodynamics, Part II , by G H Bryan, with an Appendix by Prof L Boltzmann, 1894, 1*s*

Report on Planimeters, by Prof O Henrici, F R S , 1849, 1*s*

Discussion on Agriculture and Science, Ipswich, 1895, 3*d*

Fourth Report on the Erosion of the Sea Coasts of England and Wales, 1895, 9*d*

Second Report on a Gauge for Small Screws, 1884, reprinted 1895, 6*d*

Report on giving practical effect to the Introduction of the British Association Screw Gauge, 1896, 6*d* ; 1901, 6*d*., 1903, 6*d*

Report on Proposed Modification of the Thread of the B A Screw, 1900, 6*d*

Digest of Observations on the Migration of Birds, made at Lighthouses, by W. Eagle Clarke, 1896, 6*d*

Report on the Migratory Habits of the Song-thrush and the White Wagtail, by W. Eagle Clarke, 1900, 6*d*

Report on the Migratory Habits of the Skylark and the Swallow, by W. Eagle Clarke, 1901, 6*d*.

Report on the Migratory Habits of the Fieldfare and the Lapwing, by W. Eagle Clarke, 1902, 6*d*

Report on the Migratory Habits of the Starling and the Rook, by W. Eagle Clarke, 1903, 6*d*.

Report on Tables of the Bessel Functions, 1896, 1*s*

Report on the Comparison of Magnetic Instruments, 1896, 4*d*

Report on the Position of Geography in the Educational System of the Country, 1897, 6*d*.

Report of the International Conference on Terrestrial Magnetism and Atmospheric Electricity, 1898, 6*d*

Report on the Bibliography of Spectroscopy in continuation of 1894 Report, 1898, 1*s* 6*d* ; 1901, 1*s*. 6*d*

Report on Wave-lengths, 1899, 1*s* ; 1900, with Index to Tables from 1884 to 1900, 1*s* ; 1901, 1*s*.

Tables of F (r, ν) and H (r, ν) Functions, 1899, 1*s*

Report on the Ethnological Survey of Canada, 1899, 1*s* 6*d* , 1900, 1*s* 6*d* , 1902, 1*s*

Report on Seismology, 1900, 1*s* ; 1901, 1*s* ; 1902, 1*s* ; 1903, 1*s* , 1904, 1*s* ; 1905, 1*s* ; 1906, 6*d* ; 1907, 6*d* , 1908, 1*s* , 1909, 1*s* , 1910, 1*s* , 1911, 1*s* ; 1912, 1*s*

Report on the Chemical Compounds contained in Alloys, by F H Neville, F R S , 1900, 6*d*.

The Constitution of Camphor, by A Lapworth, D Sc , 1900, 1*s*

Report on Future Dealings in Raw Produce, 1900, 6*d*

Note sur l'Unité de Pression, par le Dr C E Guillaume, 1901, 3*d*

Note on the Variation of the Specific Heat of Water, by Prof H L Callendar, 1901, 4*d*.

Report on Absorption Spectra and Chemical Constitution of Organic Substances, 1901, 1*s*.

Report on the Structure of Crystals, 1901, 1*s*

The Relative Progress of the Coal-Tar Industry in England and Germany during the past Fifteen Years, by Arthur G Green, 1901, 6*d*

The Methods for the Determination of Hydrolytic Dissociation of Salt Solutions, by R C Farmer, 1901, 6*d*.

The Application of the Equilibrium Law to the Separation of Crystals from Complex Solutions and to the Formation of Oceanic Salt Deposits, by Dr E Frankland Armstrong, 1901, 1*s*

Report on the Resistance of Road Vehicles to Traction, 1901, 3*d*

The Influence of the Universities on School Education, by the Right Rev John Percival, D D , Lord Bishop of Hereford, 1901, 3*d*

Report on Life-zones in the British Carboniferous Rocks, 1901, 6*d* ; 1902, 6*d* ; 1904, 6*d*

Our Present Knowledge of Aromatic Diazo-compounds, by Dr Gilbert Thomas Morgan, 1902, 6*d*

Report on the Teaching of Elementary Mathematics, 1902, 3*d*

Report on Women's Labour, 1903, 6*d*

Report on the Teaching of Botany in Schools, 1903, 3*d*.

Report on the Changes in the Sea Coast, 1903, 1*s*

Report on the Accuracy and Comparability of British and Foreign Statistics of International Trade, 1904, 6*d*

Report on Anthropometric Investigation in the British Isles, 1906, 1*s*.; 1907, 3*d*.

The Present Position of the Chemistry of Rubber, by S. S. Pickles, 1906, 6*d*.

The Present Position of the Chemistry of Gums, by H Robinson, 1906, 3*d*

Standardisation in British Engineering Practice, by Sir John Wolfe-Barry, K.C B , 1906, 3*d*

Melanism in Yorkshire Lepidoptera, by G. T Porritt, 1906 6*d*

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

1912

LIST OF MEMBERS

OFFICERS AND COUNCIL

AND

INSTITUTIONS RECEIVING THE REPORT

CORRECTED TO JANUARY 1, 1913

LONDON:
BURLINGTON HOUSE, PICCADILLY, W.

OFFICERS AND COUNCIL, 1912–1913.

PATRON

HIS MAJESTY THE KING

PRESIDENT

PROFESSOR E. A. SCHAFER, LL.D., D.Sc., M.D., F.R.S.

VICE-PRESIDENTS

The Hon. the Lord Provost of Dundee and Lord Lieutenant of the County of the City of Dundee.
The Right Hon. the EARL OF STRATHMORE, Lord Lieutenant of the County of Forfar.
JAMES FERGUSON, K.C., Sheriff of Forfarshire.
The Right Rev. the Moderator of the General Assembly of the Church of Scotland.
The Right Hon. the EARL OF CAMPERDOWN.
The Right Hon. LORD KINNAIRD.
Sir WILLIAM OGILVY DALGLEISH, Bart., of Errol Park.
Sir JAMES DONALDSON, LL.D., Principal of the University of St. Andrews.
Sir GEORGE BAXTER, LL.D.
The Right Rev. the Moderator of the General Assembly of the United Free Church of Scotland.
The Right Rev. BISHOP ROBBERDS, D.D., Bishop of Brechin, and Primus of the Episcopal Church of Scotland.
The Right Rev. Bishop MACFARLANE, D.D., R.C. Bishop of Dunkeld.
J. YULE MACKAY, M.D., LL.D., Principal of University College, Dundee.
The President of the Dundee Chamber of Commerce.
Sir J. K. CAIRD, Bart., LL.D.

PRESIDENT ELECT

Sir WILLIAM H. WHITE, K.C.B., LL.D., Sc.D., D.Sc., D.Eng., F.R.S.

VICE-PRESIDENTS ELECT

The Right Hon. the Lord Mayor of Birmingham.
The Most Hon. the MARQUESS OF NORTHAMPTON, K.G., Lord Lieutenant of Warwickshire.
The Worshipful the High Sheriff of Warwickshire.
The Right Hon. the EARL OF COVENTRY, Lord Lieutenant of Worcestershire.
The Right Hon. the EARL OF DARTMOUTH, Lord-Lieutenant of Staffordshire.
The Right Rev. the LORD BISHOP OF BIRMINGHAM.
The Right Hon. JOSEPH CHAMBERLAIN, D.C.L., M.P., Chancellor of the University of Birmingham.
The Vice-Chancellor of the University of Birmingham.
Sir OLIVER LODGE, D.Sc., LL.D., F.R.S., Principal of the University of Birmingham.
The Right Hon. JESSE COLLINGS, M.P., Honorary President of the Birmingham Chamber of Commerce.
Alderman the Right Hon. WILLIAM KENRICK.
The Deputy Lord Mayor of Birmingham.
Professor J. H. POYNTING, Sc.D., F.R.S.
Professor CHARLES LAPWORTH, LL.D., F.R.S.

GENERAL TREASURER

Professor JOHN PERRY, D.Sc., LL.D., F.R.S.

GENERAL SECRETARIES.

Major P. A. MACMAHON, D.Sc., LL.D., F.R.S. | Professor W. A. HERDMAN, D.Sc., F.R.S.

ASSISTANT SECRETARY

O. J. R. HOWARTH, M.A., Burlington House, London, W.

CHIEF CLERK AND ASSISTANT TREASURER

H. C. STEWARDSON, Burlington House, London, W.

LOCAL TREASURERS FOR THE MEETING AT BIRMINGHAM

Sir G. H. KENRICK | NEVILLE CHAMBERLAIN

LOCAL SECRETARIES FOR THE MEETING AT BIRMINGHAM

Prof. F. W. GAMBLE, F.R.S.
HOWARD HEATON
JOHN HUMPHREYS
W. BYNG KENRICK

[P.T.O.

ORDINARY MEMBERS OF THE COUNCIL

ARMSTRONG, Professor H E, F R S
BRABROOK, Sir EDWARD, C B
CLERK, Dr DUGALD, F R S
CRAIGIE, Major P G, C B
CROOKE, W, B A
DENDY, Professor A, F R S
FARMER, Professor J B, F R S
GRIFFITHS, Principal E H, F R S
HADDON, Dr A C, F R S
HALL, A D, F R S
HALLIBURTON, Professor W D F R S
HARTLAND, E SIDNEY, F S A.
LODGE, Sir OLIVER, F R S
LYONS, Captain H G, F R S
MARR, Dr J E, F R S
MELDOLA, Professor R, F R S
MITCHELL, Dr P CHALMERS, F R S
MYRES, Professor J L, M A
PRAIN, Sir DAVID, C I E, F R S
SHERRINGTON, Professor C S, F R S.
TRAIL, J J H, F R S
THOMPSON, Dr SILVANUS P, F R S
TROUTON, Professor F T, F R S

EX-OFFICIO MEMBERS OF THE COUNCIL

The Trustees, past Presidents of the Association, the President and Vice Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting

TRUSTEES (PERMANENT)

The Right Hon Lord AVEBURY, D C L, LL D, F R S, F L S
The Right Hon Lord RAYLEIGH, O M, M A, D C L, LL D, F R S, F R A S
Sir ARTHUR W RÜCKER, M A, D Sc LL D, F R S

PAST PRESIDENTS OF THE ASSOCIATION.

Lord Avebury, D C L, F R S
Lord Rayleigh, D C L, F R S
Sir H E Roscoe, D C L, F R S
Sir A Geikie, K C B, Pres R S
Sir William Crookes, O M, F R S
Sir W Turner, K C B, F R S
Sir A W Rücker, D Sc, F R S
Sir James Dewar, LL D F R S
Sir Norman Lockyer, K C B, F R S
Arthur J Balfour, D C L F R S
Sir E Ray Lankester, K C B, F R S
Sir David Gill, K C B, F R S
Sir Francis Darwin, F R S
Sir J J Thomson, O M, F R S
Prof T G Bonney, Sc D, F R S.
Sir W Ramsay, K C B, F R S

PAST GENERAL OFFICERS OF THE ASSOCIATION.

P L Sclater, Ph D, F R S
Prof. T G Bonney, Sc D, F R S
A. Vernon Harcourt, D C L, F R S
Sir A W Rücker, D Sc, F R S
Prof E A Schafer, F R S
Dr D H Scott, M A, F R S
Dr G Carey Foster, F R.S
Dr J G Garson

AUDITORS

Sir Edward Brabrook, C B
Professor H McLeod, LL D, F R.S

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1912

* indicates Life Members entitled to the Annual Report
§ indicates Annual Subscribers entitled to the Annual Report
‡ indicates Subscribers not entitled to the Annual Report
Names without any mark before them are Life Members, elected before 1845, not entitled to the Annual Report
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS
Names of Members whose addresses are incomplete or not known are in *italics*

Notice of changes of residence should be sent to the Assistant Secretary, Burlington House, London, W

Year of Election

1905. *à-Ababrelton, Robert, F.R G.S , F.S S. P.O Box 322, Pietermaritzburg, Natal. Care of Royal Colonial Institute, Northumberland-avenue, W C

1887 *ABBE, Professor CLEVELAND. Local Office, U.S.A. Weather Bureau, Washington, U S A

1881 *Abbott, R T. G Whitley House, Malton.

1885. *ABERDEEN, The Earl of, G C M G , LL D. Haddo House, Aberdeen

1885 ‡Aberdeen, The Countess of Haddo House, Aberdeen

1873. *ABNEY, Captain Sir W. DE W , K C B , D.C L , F R S , F R A S. (Pres. A, 1889 ; Pres L, 1903 ; Council, 1884–89, 1902–05, 1906-12) Measham Hall, Leicestershire.

1905. §Aburrow, Charles P O Box 534, Johannesburg

1869 ‡Acland, Sir C. T. Dyke, Bart , M A. Killerton, Exeter.

1877. *Acland, Captain Francis E Dyke, R A. Walwood, Banstead, Surrey

1894. *ACLAND, HENRY DYKE, F.G.S. Chy-an-Mor, Gyllyngvase, Falmouth.

1877. *Acland, Theodore Dyke, M D 19 Bryanston-square, W.

1904. ‡Acton, T. A. 41 Regent-street, Wrexham.

Year of Election

1898. ‡ACWORTH, W. M, M.A. (Pres F, 1908) The Albany, W.
1901 ‡Adam, J. Miller. 15 Walmer-crescent, Glasgow.
1887. ‡ADAMI, J. G, M A, M.D., F.R S, Professor of Pathology in McGill University, Montreal, Canada
1901 §ADAMS, JOHN, M.A, B Sc, LL D (Pres L, 1912), Professor of Education in the University of London 23 Tanza-road, Hampstead, N W.
1904 ‡Adams, W. G S, M A Department of Agriculture, Upper Merrion-street, Dublin.
1869. *ADAMS, WILLIAM GRYLLS, M A, D Sc, F R S, F G S, F C P S (Pres A, 1880, Council, 1878-85) Heathfield, Broadstone, Dorset.
1908 §Adamson, R Stephen The University, Manchester.
1898. ‡Addison, William L T Byng Inlet, Ontario, Canada
1890 ‡ADENEY, W E, D Sc, F C S Royal University of Ireland, Earlsfort-terrace, Dublin
1899 *Adie, R H, M A, B Sc 136 Huntingdon-road, Cambridge.
1908 §Adkin, Robert. 4 Lingard's-road, Lewisham, S E
1912 §Afanassieff, Apollo Physical Institute, Imperial University, St Petersburg
1908. *Agar, W. E, M A Natural History Department, The University, Glasgow.
1902 ‡Agnew, Samuel, M D Bengal-place, Lurgan
1909 ‡Aikins, J. Somerset 426 Assiniboine-avenue, Winnipeg, Canada.
1906 §Aikman, J A 6 Glencairn-crescent, Edinburgh
1871. *Ainsworth, John Stirling Harecroft, Gosforth, Cumberland.
1909. *AIRD, JOHN. Canadian Bank of Commerce, Winnipeg, Canada.
1911 §Airey, John R, M.A, B Sc. Rugby House, Marley, Yorkshire
1895 *Airy, Hubert, M D Stoke House, Woodbridge, Suffolk.
1891 *Aisbitt, M W. Mountstuart-square, Cardiff
1871 §AITKEN, JOHN, LL D, F R S, F R S E Ardenlea, Falkirk, N B
1901. ‡Aitken, Thomas, M Inst C E County Buildings, Cupar-Fife.
1884 *Alabaster, H. Milton, Grange-road, Sutton, Surrey
1886 *Albright, G S Broomsberrow Place, Ledbury
1905. ‡Albright, Miss Finstal Farm, Finstal, Bromsgrove, Worcestershire
1907. ‡*Alcock, N H, M D, D Sc* 22 *Downshire-hill, Hampstead, N W*
1900. *Aldren, Francis J, M A The Lizans, Malvern Link
1896 §Aldridge, J G W, Assoc M Inst C E 39 Victoria-street, Westminster, S W.
1905 *Alexander, J Abercromby, F S A. 24 Lawn-crescent, Kew.
1888. *Alexander, Patrick Y 3 Whitehall-court, S W
1910 *Alexander, W B, B A Western Australian Museum, Perth, West Australia
1891 *Alford, Charles J, F G S Hotel Victoria, Rome.
1883 ‡Alger, W H The Manor House, Stoke Damerel, South Devon
1883 ‡Alger, Mrs W. H The Manor House, Stoke Damerel, South Devon.
1901. *Allan, James A 21 Bothwell-street, Glasgow
1904. *Allcock, William Burt Emmanuel College, Cambridge
1879 *Allen, Rev A J. C. 34 Lensfield-road, Cambridge
1898 §ALLEN, Dr E J The Laboratory, Citadel Hill, Plymouth
1891 ‡Allen, H. A., F G.S. 28 Jermyn-street, S.W.
1907. *Allorge, M M, L. ès Sc, F.G S. University Museum, Oxford
1912 *Allworthy, S W., M.A, M.D. The Manor House, Antrim-road, Belfast.
1882. *Alverstone, The Right Hon. Lord, G.C M G., LL.D, F.R.S. Hornton Lodge, Hornton-street, Kensington, W.

Year of Election

1887. ‡Alward, G L. Enfield Villa, Waltham, Grimsby, Yorkshire.
1883 §Amery, John Sparke Druid, Ashburton, Devon.
1909. ‡Ami, H. M., M.D. Ottawa, Canada.
1884. ‡AMI, HENRY, M A, D Sc, F G S Geological Survey, Ottawa, Canada
1910. ‡Anderson, Alexander. Tower House, Dore, near Sheffield.
1905 *Anderson, C L P O Box 2162, Johannesburg.
1912 §Anderson, E. M 43 Ladysmith-road, Edinburgh
1908 ‡Anderson, Edgar. Glenavon, Merrion-road, Dublin.
1885. *ANDERSON, HUGH KERR, M A, M.D, F R.S Caius College, Cambridge
1901. *Anderson, James 10 Albion-crescent, Dowanhill, Glasgow
1892 ‡Anderson, Joseph, LL D 8 Great King-street, Edinburgh
1899 *Anderson, Miss Mary Kerr 13 Napier-road, Edinburgh.
1888 *Anderson, R Bruce 5 Westminster-chambers, S W
1887 ‡ANDERSON, Professor R. J, M D, F L S University College, and Atlantic Lodge, Salthill, Galway
1880 *ANDERSON, TEMPEST, M D, D Sc, F G S (Council, 1907 12, Local Sec 1881) 17 Stonegate, York
1901 *Anderson, Dr W Carrick 7 Scott-street, Garnethill, Glasgow.
1908 ‡Anderson, William Glenavon, Merrion-road, Dublin
1911 ‡Andrade, E N da C University College, Gower Street, W.C
1907. ‡Andrews, A W Adela-avenue, West Barnes-lane, New Malden, Surrey
1909. ‡Andrews, Alfred J. Care of Messrs Andrews, Andrews, & Co, Winnipeg, Canada
1895 ‡ANDREWS, CHARLES W, B A, D Sc, F R S British Museum (Natural History), S W
1909. ‡Andrews, G. W. 433 Main-street, Winnipeg, Canada.
1880 *Andrews, Thornton, M Inst C E Cefn Eithen, Swansea
1886 §Andrews, William, F G S Steeple Croft, Coventry
1877 §ANGELL, JOHN, F C S, F I C 6 Beacons-field, Derby-road, Withington, Manchester
1912. §Angus, Miss Mary 354 Blackness-road, Dundee
1896 ‡Annett, R C F, Assoc Inst C E 4 Buckingham-avenue, Sefton Park, Liverpool
1886 †Ansell, Joseph 27 Bennett's-hill, Birmingham
1901 ‡Arakawa, Minozi Japanese Consulate, 84 Bishopsgate-street Within, E C
1900 *ARBER, E A NEWELL, M A, F L S 52 Huntingdon-road, Cambridge
1904. *Arber, Mrs E A Newell, D Sc 52 Huntingdon-road, Cambridge
1913. *Archer, R L, M A, Professor of Education in University College, Bangor. Plas Menai, Bangor
1894 ‡Archibald, A Holmer, Court-road, Tunbridge Wells
1884 *Archibald, E Douglas. Constitutional Club, W C
1909. §Archibald, Professor E. H. Bowne Hall of Chemistry, Syracuse University, Syracuse, New York, U.S.A.
1909. ‡Archibald, H. Care of Messrs. Machray, Sharpe, & Dennistoun, Bank of Ottawa Chambers, Winnipeg, Canada.
1883 *Armistead, William Hillcrest, Oaken, Wolverhampton
1908. †Armstrong, E C. R, M R I A, F R G S Cyprus, Eglinton-road, Dublin.
1903. *ARMSTRONG, E FRANKLAND, D Sc, Ph D 27 Eastern-avenue, Reading

Year of Election

1873. *Armstrong, Henry E., Ph.D., LL.D., F.R S. (Pres. B, 1885, 1909; Pres L, 1902; Council, 1899–1905, 1909–), Professor of Chemistry in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 55 Granville-park, Lewisham, S E.
1909. ‡Armstrong, Hon. Hugh. Parliament Buildings, Kennedy-street, Winnipeg, Canada.
1905. ‡Armstrong, John Kamfersdam Mine, near Kimberley, Cape Colony.
1905. §Arnold, J. O, F.R S, Professor of Metallurgy in the University of Sheffield.
1893. *Arnold-Bemrose, H H, Sc D, F G S Ash Tree House, Osmaston-road, Derby.
1904 ‡Arunachalam, P Ceylon Civil Service, Colombo, Ceylon
1870 *Ash, Dr T. Linnington Penroses, Holsworthy, North Devon.
1903. *Ashby, Thomas, M A, D Litt The British School, Rome
1909. ‡Ashdown, J. H. 337 Broadway, Winnipeg, Canada.
1907. ‡Ashley, W. J, M A (Pres F, 1907), Professor of Commerce in the University of Birmingham 3 Yateley-road, Edgbaston, Birmingham.
Ashworth, Henry Turton, near Bolton
1903. *Ashworth, J H, D Sc 4 Cluny-terrace, Edinburgh.
1890 ‡Ashworth, J Reginald, D Sc 105 Freehold-street, Rochdale.
1875. *Aspland, W. Gaskell 50 Park Hill-road, N W.
1896. *Assheton, Richard, M A, F L S Grantchester, Cambridge.
1905 ‡Assheton, Mrs. Grantchester, Cambridge.
1908. §Astley, Rev. H. J Dukinfield, M A., Litt.D. East Rudham Vicarage, King's Lynn.
1898. *Atkinson, E Cuthbert 5 Pembroke-vale, Clifton, Bristol
1894. *Atkinson, Harold W, M A West View, Eastbury-avenue, Northwood, Middlesex
1906. ‡Atkinson, J J. Cosgrove Priory, Stony Stratford
1881 ‡Atkinson, J T. The Quay, Selby, Yorkshire
1907. ‡Atkinson, Robert E. Morland-avenue, Knighton, Leicester.
1881. ‡Atkinson, Robert William, F C S, F I.C (Local Sec. 1891.) 44 Stuart-street, Cardiff
1906. §Auden, G. A, M A, M.D. The Education Office, Edmund-street, Birmingham
1907. §Auden, H. A, D.Sc. 13 Broughton-drive, Grassendale, Liverpool
1903 ‡Austin, Charles E 37 Cambridge-road, Southport
1912 §Austin, P. C 6 Broadway-buildings, Reading.
1853. *Avebury, The Right Hon Lord, D C L, F R S (President, 1881, Trustee, 1872– ; Pres D, 1872; Council, 1865–71.) High Elms, Orpington, Kent.
1909. ‡Axtell, S W. Stobart Block, Winnipeg, Canada.

1883. *Bach-Gladstone, Madame Henri 147 Rue de Grenelle, Paris.
1906. ‡Backhouse, James. Daleside, Scarborough
1883 *Backhouse, W. A St John's, Wolsingham, R S.O., Durham.
1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.
1903. ‡Baden-Powell, Major B. 32 Prince's-gate, S.W.
1907. §Badgley, Colonel W. F., Assoc Inst C E., F.R.G.S Verecroft, Devizes.
1908. *Bagnall, Richard Siddoway Penshaw Lodge, Penshaw, Co. Durham
1905. ‡Baikie, Robert. P.O. Box 36, Pretoria, South Africa
1883. ‡Baildon, Dr. 42 Hoghton-street, Southport.

Year of Election

1883. *Bailey, Charles, M.Sc., F L S Haymesgarth, Cleeve Hill S.O., Gloucestershire.
1887. *Bailey, G H, D.Sc, Ph D Edenmor, Kinlochleven, Argyll, N.B.
1905. *Bailey, Harry Percy. Montrose, Northdown, Margate
1905. ‡Bailey, Right Hon. W. F, C B. Land Commission, Dublin
1894. *BAILY, FRANCIS GIBSON, M A. Newbury, Colinton, Midlothian.
1878. ‡BAILY, WALTER. 4 Roslyn-hill, Hampstead, N W.
1905. *Baker, Sir Augustine 56 Merrion-square, Dublin
1910. §Baker, H. F, Sc D., F R.S. St. John's College, Cambridge.
1886. §Baker, Harry, F I C. Epworth House, Moughland-lane, Runcorn
1911. §Baker, Miss Lilian, M Sc Queen's-avenue, Tunstall, Staffordshire
1907. ‡Baldwin, Walter 5 St Alban's-street, Rochdale.
1904. ‡BALFOUR, The Right Hon A J, D C L, LL D, M P, F R S, Chancellor of the University of Edinburgh (PRESIDENT, 1904) Whittingehame, Prestonkirk, N B.
1894 ‡BALFOUR, HENRY, M A (Pres H, 1904) Langley Lodge, Headington Hill, Oxford.
1905 ‡Balfour, Mrs. H Langley Lodge, Headington Hill, Oxford
1875. ‡BALFOUR, ISAAC BAYLEY, M A, D Sc, M D, F R S, F R S E, F L S (Pres D, 1894, K, 1901), Professor of Botany in the University of Edinburgh Inverleith House, Edinburgh.
1883 ‡Balfour, Mrs I. Bayley Inverleith House, Edinburgh.
1905. ‡Balfour, Mrs J Dawyck, Stobo, N B
1905. ‡Balfour, Lewis 11 Norham-gardens, Oxford
1905. ‡Balfour, Miss Vera B Dawyck, Stobo, N B
1878. *Ball, Sir Charles Bent, Bart, M D, Regius Professor of Surgery in the University of Dublin 24 Merrion-square, Dublin
1866 *BALL, Sir ROBERT STAWELL, LL D, F R S, F R A S (Pres A, 1887, Council, 1884–90, 1892–94, Local Sec 1878), Lowndean Professor of Astronomy and Geometry in the University of Cambridge The Observatory, Cambridge
1908. ‡Ball, T Elrington 6 Wilton-place, Dublin
1883. *Ball, W W Rouse, M A Trinity College, Cambridge
1905. ‡*Ballantine, Rev T R Tirmochree, Bloomfield, Belfast*
1869. ‡Bamber, Henry K, F C S 5 Westminster-chambers, Victoria-street, Westminster, S W
1890 ‡Bamford, Professor Harry, M Sc 30 Falkland-mansions, Glasgow.
1909. ‡Bampfield, Mrs E 309 Donald-street, Winnipeg, Canada.
1912. §Bancroft, Miss Nellie, B Sc, F L S 260 Normanton-road, Derby.
1905 ‡Banks, Miss Margaret Pierrepont 10 Regent-terrace, Edinburgh.
1898. ‡Bannerman, W. Bruce, F S A 4 The Waldrons, Croydon.
1909. ‡Baragar, Charles A. University of Manitoba, Winnipeg, Canada.
1910. §Barber, Miss Mary 51 Nevern-square, S W
1890 *Barber-Starkey, W J S Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George Bolesworth Castle, Tattenhall, Chester
1860. *Barclay, Robert High Leigh, Hoddesden, Herts
1887. *Barclay, Robert Sedgley New Hall, Prestwich, Manchester.
1902 ‡Barcroft, H, D.L The Glen, Newry, Co Down
1902 ‡BARCROFT, JOSEPH, M.A, B Sc., F R S. King's College, Cambridge
1911. ‡Barger, George, M A, D Sc 107 Tyrwhitt-road, St. John's, S.E.
1904. §Barker, B T P, M A. Fenswood, Long Ashton, Bristol
1906. *Barker, Geoffrey Palgrave Henstead Hall, Wrentham, Suffolk
1899. §Barker, John H, M.Inst C E. Adderley Park Rolling Mills, Birmingham
1882. *Barker, Miss J M. Sunny Bank, Scalby, Scarborough.
1910. *Barker, Raymond Inglis Palgrave. Henstead Hall, Wrentham, Suffolk.

Year of Election

1909. ‡Barlow, Lieut.-Colonel G. N. H. Care of Messrs. Cox & Co., 16 Charing Cross, S.W.
1889. ‡Barlow, H. W L, M A, M B, F C S The Park Hospital, Hither Green, S E
1883. ‡Barlow, J J 84 Cambridge-road, Southport
1885. *BARLOW, WILLIAM, F.R S, F.G S. The Red House, Great Stanmore
1905 *Barnard, Miss Annie T, M.D, B Sc 32 Chenies-street-chambers, Gower-street, W.C
1902. §Barnard, J E Park View, Brondesbury Park, N W
1881. *Barnard, William, LL B 3 New-court, Lincoln's Inn, W C
1904 ‡Barnes, Rev E W, M A, Sc D, F R S Trinity College, Cambridge
1907. §Barnes, Professor H. T., Sc D, F R S. McGill University, Montreal, Canada
1909. *Barnett, Miss Edith A Holm Leas, Worthing.
1881. ‡BARR, ARCHIBALD, D Sc, M Inst C E (Pres G, 1912), Professor of Civil Engineering in the University of Glasgow
1902 *Barr, Mark. Gloucester-mansions, Harrington-gardens, S.W.
1904 ‡Barrett, Arthur 6 Mortimer-road, Cambridge
1872 *BARRETT, Sir W. F, F R S, F R S E, M R I A 6 De Vesci-terrace, Kingstown, Co Dublin
1874. *BARRINGTON, R M, M A, LL B, F L S Fassaroe, Bray, Co. Wicklow
1874. *Barrington-Ward, Rev Mark J, M A, F L S, F R G S The Rectory, Duloe S O, Cornwall
1893. *BARROW, GEORGE, F G S. 28 Jermyn-street, S W.
1896 §Barrowman, James Staneacre, Hamilton, N B.
1908 ‡Barry, Gerald H Wiglin Glebe, Carlow, Ireland.
1884. *Barstow, Miss Frances A Garrow Hill, near York
1890 *Barstow, J J Jackson The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs The Lodge, Weston-super-Mare
1892 ‡Bartholomew, John George, F R S E, F R G S Newington House, Edinburgh
1858 *Bartholomew, William Hamond, M Inst C E Ridgeway House, Cumberland-road, Hyde Park, Leeds
1909. ‡Bartleet, Arthur M. 138 Hagley-road, Edgbaston, Birmingham.
1909. ‡Bartlett, C Bank of Hamilton-building, Winnipeg, Canada.
1893 *Barton, Edwin H, D Sc, F R S E, Professor of Experimental Physics in University College, Nottingham
1908. ‡Barton, Rev. Walter John, B A, F.R G S The College, Winchester.
1904. *Bartrum, C O, B Sc 32 Willoughby-road, Hampstead, N W.
1888 *BASSET, A B, M A, F R S Fledborough Hall, Holyport, Berkshire
1891 ‡Bassett, A B Cheverell, Llandaff.
1866 *BASSETT, HENRY 26 Belitha-villas, Barnsbury, N.
1911 *Bassett, Henry, jun, D Sc., Ph D University College, Reading
1889 ‡BASTABLE, Professor C F, M A, F S S (Pres F, 1894) 52 Brighton-road, Rathgar, Co Dublin
1871. ‡BASTIAN, H CHARLTON, M A, M D, F R S, F L S, Emeritus Professor of the Principles and Practice of Medicine in University College, London Fairfield, Chesham Bois, Bucks
1912 §Bastian, Staff-Surgeon William, R N Chesham Bois, Buckinghamshire
1883. ‡BATEMAN, Sir A. E, K C M G. Woodhouse, Wimbledon Park, S.W.
1905. *Bateman, Mrs F D Kilmorie, Ilsham-drive, Torquay, Devon.
1907 *BATEMAN, HARRY. The University, Manchester
1884 ‡BATESON, Professor WILLIAM, M.A, F.R.S (Pres D, 1904.) Manor House, Merton, Surrey.

Year of Election

1881. *BATHER, FRANCIS ARTHUR, M A, D Sc, F.R.S, F.G S. British Museum (Natural History), S W.
1906 §Batty, Mrs. Braithwaite. Ye Gabled House, The Parks, Oxford.
1904 ‡Baugh, J H Agar 92 Hatton-garden, E C
1909. §Bawlf, Nicholas Assiniboine-avenue, Winnipeg, Canada.
1912 *Baxter, Miss Evelyn V Roselea, Kirkton of Largo, Fife.
1912. *Bayliss, W. M, M A, D Sc, F R S, Assistant Professor of Physiology in University College, London, W C
1876. *BAYNES, ROBERT E, M A Christ Church, Oxford
1887 *Baynes, Mrs. R E. 2 Norham-gardens, Oxford
1883 *Bazley, Gardner S. Hatherop Castle, Fairford, Gloucestershire
Bazley, Sir Thomas Sebastian, Bart, M A Kilmorie, Ilsham drive, Torquay, Devon
1909 *BEADNELL, H J LLEWELLYN, F G S Hafod, Llandinam, Montgomeryshire.
1889 §BEARE, Professor T. HUDSON, B Sc, F R S E, M Inst C E. The University, Edinburgh
1905 ‡Beare, Mrs T Hudson 10 Regent-terrace, Edinburgh
1904 §Beasley, H C 25A Prince Alfred-road, Wavertree, Liverpool
1905 ‡Beattie, Professor J C, D Sc, F R S E South African College, Cape Town
1910 ‡Beattie, James M 12 Caxton-road, Sheffield
1900 ‡Beaumont, Professor Roberts, M I Mech E The University, Leeds.
1887 *Beaumont, W J The Laboratory, Citadel Hill, Plymouth
1885 *BEAUMONT, W W, M Inst C E. Outer Temple, 222 Strand, W C
1887 *BECKETT, JOHN HAMPDEN Corbar Hall, Buxton, Derbyshire
1904 §Beckit, H O Cheney Cottage, Headington, Oxford.
1885 ‡BEDDARD, FRANK E, M A, F R S, F Z S, Prosector to the Zoological Society of London, Regent's Park, N W
1911. ‡Beddow, Fred, D Sc, Ph D 2 Pier-mansions, Southsea
1904 *Bedford, T G, M A 13 Warkworth-street, Cambridge.
1891 ‡Bedlington, Richard Gadlys House, Aberdare
1878 ‡BEDSON, P PHILLIPS, D Sc, F C S (Local Sec 1889), Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne
1901. *BEILBY, G T, LL.D, F R S. (Pres B, 1905) 11 University-gardens, Glasgow
1905. ‡Beilby, Hubert 11 University-gardens, Glasgow
1891. *Belinfante, L L, M Sc, Assist Sec G S Burlington House, W.
1909. ‡BELL, C N (Local Sec 1909) 121 Carlton-street, Winnipeg, Canada
1894. ‡BELL, F JEFFREY, M A, F Z S British Museum, S W
1900 *Bell, Henry Wilkinson Beech Cottage, Rawdon, near Leeds
1870. *BELL, J CARTER, A R S.M The Cliff, Higher Broughton, Manchester
1883 *Bell, John Henry 102 Leyland-road, Southport
1888. *Bell, Walter George, M A Trinity Hall, Cambridge.
1908 *Bellamy, Frank Arthur, M A, F R.A S. University Observatory Oxford
1904 ‡Bellars, A E Magdalene College, Cambridge
1883 *Bennett, Laurence Henry. The Elms, Paignton, South Devon.
1901. ‡Bennett, Professor Peter 207 Bath-street, Glasgow.
1909. *Bennett, R. B., K.C. Calgary, Alberta, Canada
1909. ‡Benson, Miss C. C. Terralta, Port Hope, Ontario, Canada.
1903. §Benson, D. E. Queenwood, 12 Irton-road, Southport.
1901. *Benson, Miss Margaret J, D.Sc Royal Holloway College, Egham.
1887. *Benson, Mrs. W J. 5 Wellington-court, Knightsbridge, S.W

Year of
Election.

1898. *Bent, Mrs Theodore. 13 Great Cumberland-place, W.
1904. ‡BENTLEY, B. H, M.A, Professor of Botany in the University of Sheffield
1905. *Bentley, Wilfred Rein Wood, Huddersfield.
1908. ‡Benton, Mrs Evelyn M. Kingswear, Hale, Altrincham, Cheshire.
1896. *Bergin, William, M.A, Professor of Natural Philosophy in University College, Cork.
1894. §BERKELEY, The Earl of, F.R S. F C S (Council, 1909–10.) Foxcombe, Boarshill, near Abingdon
1905. *BERNACCHI, L. C, F R G S. 54 Inverness-terrace, W
1906 *Bernays, Albert Evan 3 Priory-road, Kew, Surrey.
1898 §Berridge, Miss C E 107 Albert Palace-mansions, Battersea Park, S.W.
1894. §BERRIDGE, DOUGLAS, M A, F C S The College, Malvern
1908. *Berridge, Miss Emily M Dunton Lodge, The Knoll, Beckenham.
1908 *Berry, Arthur J 14 Regent-street, Cambridge
1904 §Berry, R A, Ph D, West of Scotland Agricultural College, 6 Blythswood-square, Glasgow.
1905. ‡Bertrand, Captain Alfred Champel, Geneva
1862. ‡BESANT, WILLIAM HENRY, M A, Sc D, F.R S. St John's College, Cambridge
1880 *BEVAN, Rev JAMES OLIVER, M A, F S A, F G S Chillenden Rectory, Canterbury
1904 *Bevan, Professor P V, M A. Hillside, Egham
1906. ‡*Bevan-Lewis, W, M D West Riding Asylum, Wakefield*
1884. *Beverley, Michael, M D 54 Prince of Wales-road, Norwich
1903. ‡Bickerdike, C F 1 Boverney-road, Honor Oak Park, S E
1888. *Bidder, George Parker Savile Club, Piccadilly, W.
1910. ‡Biddlecombe, A. 50 Grainger-street, Newcastle-on-Tyne.
1904 §BIGG-WITHER, Colonel A C F R A S Tilthams, Godalming, Surrey
1882. ‡*Biggs, C H W, F C S Glebe Lodge, Champion-hill, S E*
1911. §BILES, J H, LL D, D Sc. (Pres G, 1911), Professor of Naval Architecture in the University of Glasgow 10 University-gardens, Glasgow
1898. ‡Billington, Charles Heimath, Longport, Staffordshire
1901. *Bilsland, Sir William, Bart, J P 28 Park-circus, Glasgow.
1908. *Bilton, Edward Barnard Graylands, Wimbledon Common, S W.
1887 *Bindloss, James B Elm Bank, Buxton
1884 *Bingham, Colonel Sir John E, Bart West Lea, Ranmoor, Sheffield.
1881. ‡BINNIE, Sir ALEXANDER R, M Inst C E, F G S (Pres G, 1900.) 77 Ladbroke-grove, W
1910. *Birchenough, C, M A 8 Severn-road, Sheffield
1887 *Birley, H K Penrhyn, Irlams o' th' Height, Manchester
1904. ‡Bishop, A W Edwinstowe, Chaucer-road, Cambridge
1911. *Bishop, Major C F, R A The Castle, Tynemouth, Northumberland.
1906 §Bishop, J L Customs and Excise Office, Leeds
1894. ‡Bisset, James, F R S E 9 Greenhill-park, Edinburgh
1910. ‡Bisset, John. Thornhill, Insch, Aberdeenshire
1886. *Bixby, General W H 735 Southern-building, Washington, U S A.
1909. ‡Black, W. J., Principal of Manitoba Agricultural College, Winnipeg, Canada.
1901 §Black, W P M 136 Wellington-street, Glasgow.
1903 *BLACKMAN, F F, M A, D Sc, F R S (Pres K, 1908) St John's College, Cambridge
1908 §BLACKMAN, Professor V. H., M A., Sc D. Imperial College of Science and Technology, S W.
1909. ‡Blaikie, Leonard, M A. Civil Service Commission, Burlington-gardens, W.

Year of Election

1910. ‡Blair, R., M.A. London County Council, Spring-gardens, S.W.
1902. ‡Blake, Robert F, F I C Queen's College, Belfast.
1900. *Blamires, Joseph Bradley Lodge, Huddersfield.
1905. ‡Blamires, Mrs. Bradley Lodge, Huddersfield
1904. ‡Blanc, Dr Gian Alberto Istituto Fisico, Rome
1884 *Blandy, William Charles, M A 1 Friar-street, Reading.
1887. *Bles, Edward J, M A, D Sc Elterholm, Madingley-road, Cambridge.
1884. *Blish, William G Niles, Michigan, U S A
1902. ‡Blount, Bertram, F I C 76 & 78 York-street, Westminster, S W
1888 ‡Bloxsom, Martin, B A, M Inst C E Hazelwood, Crumpsall Green, Manchester
1909 §Blumfield, Joseph, M D 35 Harley-street, W
. Blyth, B Hall 135 George-street, Edinburgh
1887. *Boddington, Henry Pownall Hall, Wilmslow, Manchester
1908. §Boeddicker, Otto, Ph D Birr Castle Observatory, Birr, Ireland.
1887. *Boissevain, Gideon Maria 4 Tesselschade-straat, Amsterdam.
1911. §Bolland, B. G C. Survey Department, Giza, Cairo, Egypt
1898. §Bolton, H, F R S E The Museum, Queen's-road, Bristol
1894. §Bolton, John 15 Cranley-gardens, Muswell Hill, N
1898. *Bonar, James, M A, LL D (Pres F, 1898, Council, 1899–1905) The Mint, Ottawa, Canada
1909. ‡Bonar, Thomson, M D 114 Via Babuino, Piazza di Spagna, Rome
1912. *Bond, C I, F R C S. Springfield-road, Leicester
1909. ‡Bond, J H R, M B. 167 Donald-street, Winnipeg, Canada
1908. ‡Bone, Professor W. A, D Sc, F R S. The University, Leeds
1871 *Bonney, Rev Thomas George, Sc D, LL D, F R S, F S A, F G S (President, 1910, Secretary, 1881–85, Pres C, 1886) 9 Scroope-terrace, Cambridge
1911. ‡Bonny, W Naval Store office, The Dockyard, Portsmouth.
1888. ‡Boon, William Coventry
1893 ‡Boot, Sir Jesse Carlyle House, 18 Burns-street, Nottingham.
1890. *Booth, Right Hon Charles, Sc D, F R S, F S S 28 Campden House Court, Kensington, W
1883 ‡Booth, James Hazelhurst, Turton
1910. §Booth, John, M C E, B Sc The Gables, Berkeley-street, Hawthorn, Melbourne Australia.
1908. §Booth, Robert, J.P. Bartra Hall, Dalkey, Co. Dublin.
1883 ‡Boothroyd, Benjamin Weston-super-Mare
1901 *Boothroyd, Herbert E, M A, B Sc Sidney Sussex College, Cambridge
1912. §Borgmann, Professor J J, D Ph., LL D Physical Institute, The University, St Petersburg.
1882. §Borns, Henry, Ph D 5 Sutton Court-road, Chiswick, W
1901. ‡Borradaile, L A, M A Selwyn College, Cambridge
1876. *Bosanquet, R H M, M A, F R S, F R A S Castillo Zamora, Realejo-Alto, Teneriffe
1903. *Bosanquet, Robert C, M A., Professor of Classical Archæology in the University of Liverpool. Institute of Archæology, 40 Bedford-street, Liverpool
1896. ‡Bose, Professor J C, C I E, M A, D Sc Calcutta, India
1881. §Bothamley, Charles H, M Sc, F I C, F C S, Education Secretary, Somerset County Council, Weston-super-Mare
1871. *Bottomley, James Thomson, M A, LL.D, D Sc, F R S, F R S E., F.C S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow
1892. *Bottomley, W. B. M.A., Professor of Botany in King's College, W C.

Year of Election

1909. §Boulenger, C. L. 8 Courtfield-road, S.W.
1905. §Boulenger, G A , F R.S (Pres D, 1905) 8 Courtfield-road, S.W.
1905 §Boulenger, Mrs 8 Courtfield-road, S.W.
1903 §Boulton, W. S , B Sc., F G S , Professor of Geology in University College, Cardiff. 26 Archer-road, Penarth
1911. ‡Bourdillon, R Balliol College, Oxford.
1883 ‡Bourne, Sir A G , K C I.E., D Sc , F R S , F L S Adyar, Madras
1893. *Bourne, G C , M A., D Sc , F.R S , F L S (Pres D, 1910 ; Council, 1903-09 ; Local Sec 1894), Linacre Professor of Comparative Anatomy in the University of Oxford Savile House, Mansfield-road, Oxford
1881. *Bower, F O , D Sc , F R S , F R S E , F L S (Pres K, 1898 ; Council, 1900–06), Regius Professor of Botany in the University of Glasgow
1898. *Bowker, Arthur Frank, F R G S , F G S Whitehill, Wrotham, Kent.
1856. *Bowlby, Miss F E 7 South Bailey, Durham
1908. §Bowles, E Augustus, M A , F L S. Myddelton House, Waltham Cross, Herts
1898 ‡Bowley, A L , M A (Pres F, 1906 , Council, 1906–11) North court-avenue, Reading
1880 ‡Bowly, Christopher Cirencester
1887. ‡Bowly, Mrs Christopher Cirencester.
1899. *Bowman, Herbert Lister, M A , D Sc , F G S , Professor of Mineralogy in the University of Oxford Magdalen College, Oxford.
1899. *Bowman, John Herbert Greenham Common, Newbury
1887. §Box, Alfred Marshall Woodlands, Magrath Avenue, Cambridge.
1901 ‡Boyd, David T Rhinsdale, Ballieston, Lanark
1892 ‡Boys, Charles Vernon, F.R S (Pres A, 1903 , Council, 1893–99, 1905–08) 66 Victoria-street, S W
1872. *Brabrook, Sir Edward, C B , F S A (Pres H, 1898 ; Pres F, 1903 , Council, 1903–10 , 1911–) 178 Bedford-hill, Balham, S W.
1894. *Braby, Ivon Helena, Alan-road, Wimbledon, S W.
1893 §Bradley, F L Ingleside, Malvern Wells
1904 *Bradley, Gustav Council Offices, Goole
1899. *Bradley, J W , Assoc M Inst C E Westminster City Hall, Charing Cross-road, W C
1903. *Bradley, O Charnock, D Sc , M D , F R S E Royal Veterinary College, Edinburgh
1892. ‡Bradshaw, W Carisbrooke House, The Park, Nottingham.
1863. ‡Brady, George S , M D , LL D , F R S. Park Hurst, Endcliffe, Sheffield
1911 §Bragg, W. H , M A , F R S , Professor of Mathematics in the University of Leeds
1905 §Brakhan, A Clare Bank, The Common, Sevenoaks
1906. §Branfield, Wilfrid 4 Victoria-villas, Upperthorpe, Sheffield
1885. *Bratby, William, J P Alton Lodge, Lancaster Park Harrogate.
1905 ‡Brausewetter, Miss Roedean School, near Brighton.
1909. §Bremner, Alexander. 38 New Broad-street, E C.
1905. ‡Bremner, R. S. Westminster-chambers, Dale-street, Liverpool.
1905. ‡Bremner, Stanley Westminster-chambers, Dale-street, Liverpool.
1913 §Brenchley, Miss Winifred E , D Sc , F L S Rothamsted Experimental Station, Harpenden, Herts.
1902. *Brereton, Cloudesley. Briningham House, Briningham, S.O., Norfolk.

Year of Election

1909. *Breton, Miss Adela C. Care of Wilts and Dorset Bank, Bath.
1905. §Brewis, E 27 Winchelsea-road, Tottenham, N.
1908. §Brickwood, Sir John. Branksmere, Southsea.
1907. *Bridge, Henry Hamilton Fairfield House, Droxford, Hants.
1912 §Bridgman, F. J, F L S. Zoological Department, University College, W C
1904. *Briggs, William, M A, LL D, F R A S Burlington House, Cambridge
1909. §Briggs, Mrs. Owlbrigg, Cambridge.
1908. ‡Brindley, H. H. 4 Devana-terrace, Cambridge.
1893. ‡Briscoe, Albert E., B.Sc, A.R.C Sc. The Hoppet, Little Baddow, Chelmsford
1904. ‡Briscoe, J. J. Bourn Hall, Bourn, Cambridge
1905. §Briscoe, Miss. Bourn Hall, Bourn, Cambridge
1898. ‡Bristol, The Right Rev G F. Browne, D D, Lord Bishop of. 17 The Avenue, Clifton, Bristol.
1879 *Brittain, W. H, J P, F R G S Storth Oaks, Sheffield
1905. *Broadwood, Brigadier-General R. G The Deodars, Bloemfontein, South Africa
1905 ‡Brock, Dr B G P O. Box 216, Germiston, Transvaal.
1907 ‡Brockington, W. A, M A Leicestershire County Council, 38 Bowling Green-street, Leicester
1896. *Brocklehurst, S Olinda, Sefton Park, Liverpool
1901. ‡Brodie, T. G., M D., F R.S., Professor of Physiology in the University of Toronto. The University, Toronto, Canada.
1883. *Brodie-Hall, Miss W L Havenwood, Peaslake, Gomshall, Surrey.
1903. ‡Brodrick, Harold, M A, F G.S. (Local Sec 1903) 7 Aughton-road, Birkdale, Southport
1904 ‡Bromwich, T J. I'A, M A, F R S 1 Selwyn-gardens, Cambridge
1906 ‡Brook, Stanley 18 St George's-place, York
1911 §Brooke, Colonel Charles, K, F R G S Army and Navy Club, Pall Mall, S W.
1906 *Brooks, F T 102 Mawson-road, Cambridge
1883 *_Brotherton, E A 16 St James's-place, S W_
1883 *Brough, Mrs Charles S 4 Spencer-road, Southsea
1886. ‡Brough, Joseph, LL D, Professor of Logic and Philosophy in University College, Aberystwyth
1913 §Brown, Professor A J, M Sc, F R S West Heath House, Northfield, Birmingham
1905 ‡Brown, A R Trinity College, Cambridge
1863 *Brown, Alexander Crum, M D, LL D, F R S, F R S E, V P C S. (Pres B, 1874, Local Sec. 1871) 8 Belgrave-crescent, Edinburgh
1883. ‡Brown, Mrs Ellen F Campbell 27 Abercromby-square, Liverpool
1905. §Brown, Professor Ernest William, M A, D.Sc, F R S Yale University, New Haven, Conn, U S A.
1903 ‡Brown, F W. 6 Rawlinson-road, Southport
1870. §Brown, Horace T, LL D, F.R S, F G S (Pres B, 1899, Council, 1904–11) 52 Nevern-square, S W
1881 *Brown, John, M D. Rosebank, Cape of Good Hope.
1895. *Brown, John Charles. 39 Burlington-road, Sherwood, Nottingham
1882 *Brown, Mrs Mary Rosebank, Cape of Good Hope.
1898 §Brown, Nicol, F G.S 4 The Grove, Highgate, N
1901. ‡Brown, Professor R. N. Rudmose, D Sc The University, Sheffield.
1908. §Brown, Sidney G. 52 Kensington Park-road, W.

Year of Election

1905. §Brown, Mrs. Sidney G. 52 Kensington Park-road, W.
1910 *Brown, Sidney J R. 52 Kensington Park-road, W.
1912. §Brown, T Graham. The University, Liverpool.
1884. ‡Brown, W. G. University of Missouri, Columbia, Missouri, U.S A
1908. ‡Brown, William, B Sc. 48 Dartmouth-square, Dublin.
1912. §Brown, Dr William. Thornfield, Horley, Surrey.
1906. ‡Browne, Charles E, B Sc Christ's Hospital, West Horsham.
1900. *Browne, Frank Balfour, M A, F R S E, F Z.S. Claremont, Holywood, Co. Down.
1908. ‡Browne, Rev. Henry, M A. University College, Dublin
1895 *Browne, H T. Doughty 6 Kensington House, Kensington-court, W
1879. ‡BROWNE, Sir J CRICHTON, M D, LL D, F R S, F R.S E. 61 Carlisle-place-mansions, Victoria-street, S W.
1905 *Browne, James Stark, F R A S The Red House, Mount-avenue, Ealing, W
1883 ‡Browning, Oscar, M A King's College, Cambridge
1912. §Browning, T B, M A 19 Aldermary-road, Bromley, Kent.
1905. §BRUCE, Colonel Sir DAVID, C B, F R S, A M S (Pres. I, 1905) Royal Society Commission, Kasu Hill (near Mvera), Central Angoniland, Nyasaland Protectorate, British Central Africa
1905. ‡Bruce, Lady 3P Artillery-mansions, Victoria-street, S W
1893 ‡Bruce, William S, LL D, F.R S E Antarctica, Joppa, Edinburgh.
1902. ‡*Bruce-Kingsmill, Major J., F C S. 4 St Ann's-square, Manchester.*
1900. *Brumm, Charles Lismara, Grosvenor-road, Birkdale, Southport.
1896. *Brunner, Right Hon Sir J T, Bart Druid's Cross, Wavertree, Liverpool
1868. ‡BRUNTON, Sir T. LAUDER, Bart, M D, Sc D, F R S (Council, 1908–12) 10 Stratford-place, Cavendish-square, W.
1897. *Brush, Charles F Cleveland, Ohio, U S A
1886. *BRYAN, G H, D Sc, F R S, Professor of Mathematics in University College, Bangor
1894 ‡Bryan, Mrs R P Plas Gwyn, Bangor
1884 *BRYCE, Rev Professor GEORGE, D D, LL D Kilmadock, Winnipeg, Canada
1909. ‡Bryce, Thomas H., M D., Professor of Anatomy in the University of Glasgow 2 The College, Glasgow
1902 *Bubb, Miss E Maude Ullenwood, near Cheltenham
1890 §Bubb, Henry. Ullenwood, near Cheltenham
1902 *Buchanan, Miss Florence, D Sc University Museum, Oxford.
1905. §Buchanan, Hon Sir John Clareinch, Claremont, Cape Town.
1871 ‡BUCHANAN, JOHN YOUNG, M A, F R S, F R S E, F R G S., F C S Christ's College, Cambridge
1909. ‡Buchanan, W. W. P O. Box 1658, Winnipeg, Canada.
1884 *Buckmaster, Charles Alexander, M A, F C S 16 Heathfield-road, Mill Hill Park, W.
1904. ‡Buckwell, J C. North Gate House, Pavilion, Brighton.
1893. §BULLEID, ARTHUR, F S A Dymboro, Midsomer Norton, Bath.
1909. ‡BULYEA, The Hon. G. H. V. Edmonton, Alberta, Canada.
1905. ‡Burbury, Mrs. A. A 15 Melbury-road, W.
1905. ‡Burbury, Miss A D. 15 Melbury road, W.
1907. ‡Burch, George J., M A., D.Sc, F R S. 28 Norham-road, Oxford.
1881. ‡Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W.
1905 ‡Burdon, E. R., M.A. Ikenhilde, Royston, Herts.

Year of Election.

1894. ‡**Burke, John B. B.** Trinity College, Cambridge.
1884. *Burland, Lieut.-Colonel Jeffrey H. 342 Sherbrooke-street West, Montreal, Canada.
1899. ‡Burls, H. T., F.G.S. 2 Verulam-buildings, Gray's Inn, W C.
1904. ‡Burn, R H 21 Stanley-crescent, Notting-hill, W
1909. ‡Burns, F. D. 203 Morley-avenue, Winnipeg, Canada.
1908. ‡Burnside, W. Snow, D Sc , Professor of Mathematics in the University of Dublin. 35 Raglan-road, Dublin.
1905. ‡Burroughes, James S , F R G S. The Homestead, Seaford, Sussex.
1909. ‡Burrows, Theodore Arthur. 187 Kennedy-street, Winnipeg, Canada.
1910. ‡Burt, Cyril The University, Liverpool.
1894. ‡Burton, C. V. Boar's Hill, Oxford.
1909. ‡Burton, E. F. 129 Howland-avenue, Toronto, Canada.
1911. §Burton, J. H. County Education Office, Weston-super-Mare.
1904 ‡Burtt, Arthur H , D Sc. 4 South View, Holgate, York.
1906. ‡Burtt, Philip Swarthmore, St George's-place, York
1909. ‡Burwash, E. M., M A. New Westminster, British Columbia, Canada.
1887. *Bury, Henry Mayfield House, Farnham, Surrey
1899. ‡Bush, Anthony 43 Portland-road, Nottingham
1895. ‡Bushe, Colonel C K , F G S 19 Cromwell-road, S W.
1906 §Bushell, H A. Melton House, Holgate Hill, York.
1908 *Bushell, W F Gresham's School, Holt, Norfolk
1910. ‡Butcher, Miss. 25 Earl's Court-square, S.W.
1884 *Butcher, William Deane, M R C S Eng Holyrood, 5 Cleveland-road, Ealing, W
1884 *Butterworth, W Oceola, 9 Knowles-road, St Anne's-on-the-Sea, Lancashire
1887 *Buxton, J H Clumber Cottage, Montague-road, Felixstowe
1899 ‡Byles, Arthur R 'Bradford Observer,' Bradford, Yorkshire

1908 ‡Cadic, Edouard, D Litt. Mon Caprice, Pembroke Park, Dublin.
1892 ‡Cadell, H. M , B Sc , F.R S E Grange, Linlithgow
1913. §Cadman, John, D.Sc., Professor of Mining in the University of Birmingham 61 Wellington-road, Edgbaston, Birmingham.
1912. §Caine, Nathaniel Spital, Cheshire
1861. *Caird, Sir James Key, Bart , LL D 8 Magdalen Yard-road Dundee
1901 ‡Caldwell, Hugh Blackwood, Newport, Monmouthshire.
1907 ‡Caldwell, K. S St Bartholomew's Hospital, S E
1908. §Caldwell, Colonel R. T., M A , LL M , LL.D , Master of Corpus Christi College, Cambridge
1897 †Callendar, Hugh L , M A , LL D , F R S (Pres A, 1912, Council, 1900–06), Professor of Physics in the Imperial College of Science and Technology, S W.
1911. §Calman, W. T., D Sc. British Museum (Natural History), Cromwell-road, S.W.
1911. §Cameron, Alexander T. Physiological Department, University of Manitoba, Winnipeg.
1857. ‡**Cameron, Sir Charles A., C B., M D** 51 Pembroke-road, Dublin.
1909. ‡Cameron, D. C. 65 Roslyn-road, Winnipeg, Canada.
1896. §Cameron, Irving H., LL D , Professor of Surgery in the University of Toronto. 307 Sherbourne-street, Toronto, Canada.
1909. ‡Cameron, Hon. Mr. Justice J. D. Judges' Chambers, Winnipeg, Canada.

Year of Election

1901. §Campbell, Archibald. Park Lodge, Albert-drive, Pollokshields, Glasgow.
1897. ‡Campbell, Colonel J. C. L. Achalader, Blairgowrie, N.B
1909. *Campbell, R. J. Rideau Hall, 85 Kennedy-street, Winnipeg, Canada.
1909. ‡Campbell, Mrs. R. J. Rideau Hall, 85 Kennedy-street, Winnipeg, Canada.
1902. ‡Campbell, Robert. 21 Great Victoria-street, Belfast.
1912 §Campbell, Dr. Robert Geological Department, The University, Edinburgh.
1890. ‡CANNAN, Professor EDWIN, M.A., LL D , F S.S. (Pres. F, 1902.) 11 Chadlington-road, Oxford.
1905. ‡Cannan, Gilbert. King's College, Cambridge.
1897. §Cannon, Herbert. Alconbury, Bexley Heath, Kent
1904. ‡Capell, Rev. G M Passenham Rectory, Stony Stratford.
1911. §Capon, R. S. 49A Rodney-street, Liverpool.
1905 *Caporn, Dr. A. W Roeland-street Baths, Cape Town.
1894 ‡CAPPER, D S , M A , Professor of Mechanical Engineering in King's College, W C.
1887. ‡CAPSTICK, J. W. Trinity College, Cambridge
1896 *Carden, H. Vandeleur. Fir Lodge, Broomfield, Chelmsford.
1913 §Carlier, E Wace, M Sc , M D , F.R S E , Professor of Physiology in the University of Birmingham. The University, Edmund-street, Birmingham
1902. ‡Carpenter, G H , B Sc , Professor of Zoology in the Royal College of Science, Dublin.
1906. *Carpenter, H C. H 11 Oak-road, Withington, Manchester.
1905 §Carpmael, Edward, F R A S , M.Inst C E 24 Southampton-buildings, Chancery-lane, W C.
1912 *Carr, H. Wildon, D Litt More's Garden, Cheyne-walk, S W
1910 §Carr, Henry F. Broadparks, Pinhoe, near Exeter
1893. ‡CARR, J WESLEY, M A , F.L S , F G S , Professor of Biology in University College, Nottingham
1906. *Carr, Richard E. Sylvan Mount, Sylvan-road, Upper Norwood, S.E.
1889. ‡Carr-Ellison, John Ralph Hedgeley, Alnwick
1911. §Carruthers, R. G , F.G S. Geological Survey Office, 33 George-square, Edinburgh
1867. ‡CARRUTHERS, WILLIAM, F R S , F L S , F G S (Pres D, 1886) 44 Central-hill, Norwood, S E
1886. ‡CARSLAKE, J BARHAM (Local Sec 1886) 30 Westfield-road, Birmingham.
1899. ‡Carslaw, H S , D.Sc , Professor of Mathematics in the University of Sydney, N S.W
1911. §Carter, Godfrey, M.B 4 Lawson-road, Broomhill, Sheffield.
1900. *Carter, W. Lower, M A , F.G S. Bolbec, Grange Road, Watford.
1896. ‡Cartwright, Miss Edith G 21 York Street-chambers, Bryanston-square, W.
1878. *Cartwright, Ernest H., M.A., M D Myskyns, Ticehurst, Sussex.
1870. §Cartwright, Joshua, M Inst C.E , F S I 21 Parsons-lane, Bury, Lancashire.
1862. ‡Carulla, F J. R. 84 Rosehill-street, Derby
1894. ‡Carus, Dr Paul. La Salle, Illinois, U.S.A.
1901. ‡Carver, Thomas A. B , D Sc , Assoc.M Inst C.E. 118 Napiershall-street, Glasgow.
1897. *Case, Willard E. Auburn, New York, U S A
1873. *Cash, William, F.G.S. 26 Mayfield-terrace South, Halifax.
1908. *Cave, Charles J P , M.A. Ditcham Park, Petersfield.
1910. §Chadburn, A. W. Brincliffe Rise, Sheffield.

Year of Election.

1905. *Challenor, Bromley, M.A. The Firs, Abingdon.
1905. *Challenor, Miss E M. The Firs, Abingdon.
1910. §Chalmers, Stephen D. 25 Cornwall-road, Stroud Green, N
1913. §CHAMBERLAIN, NEVILLE. (LOCAL TREASURER, 1913.) Westbourne, Edgbaston, Birmingham.
1901. §Chamen, W. A. South Wales Electrical Power Distribution Company, Royal-chambers, Queen-street, Cardiff
1905. ‡Champion, G. A. Haraldene, Chelmsford-road, Durban, Natal
1881. *Champney, John E 27 Hans-place, S W
1908. ‡Chance, Sir Arthur, M D 90 Merrion-square, Dublin
1888. ‡Chandler, S. Whitty, B A St George's, Cecil-road, Boscombe.
1907. *Chapman, Alfred Chaston, F I C. 8 Duke-street, Aldgate, E C
1902 *Chapman, D L Jesus College, Oxford
1910. ‡Chapman, J. E Kinross.
1899. §CHAPMAN, Professor SYDNEY JOHN, M A, M.Com. (Pres F, 1909.) Burnage Lodge, Levenshulme, Manchester.
1912. *Chapman, Sydney, D Sc, B A, F R A S Royal Observatory, Greenwich, S E.
1910. ‡Chappell, Cyril. 73 Neill-road, Sheffield
1905. ‡Chassigneux, E 12 Tavistock-road, Westbourne-park, W
1904. *Chattaway, F. D, M A, D Sc, Ph D, F R S 103 Woodstock-road, Oxford
1886. *CHATTOCK, A P. Heathfield Cottage, Crowcombe, Somerset.
1904. *Chaundy, Theodore William, B A 49 Broad-street, Oxford
1900. §Cheesman, W Norwood, J P, F L S The Crescent, Selby
1874. *Chermside, Lieut -General Sir Herbert, R E, G C M G, C B New-stead Abbey, Nottingham
1908. ‡Cherry, Right Hon Lord Justice 92 St Stephen's Green, Dublin
1910. ‡Chesney, Miss Lilian M, M B 381 Glossop-road, Sheffield
1879. *Chesterman, W Belmayne, Sheffield
1911 *Chick, Miss H, D Sc Chestergate, Park-hill, Ealing, W
1908 ‡Chill, Edwin, M D Westleigh, Mattock-road, Ealing, W.
1883 ‡Chinery, Edward F, J P Lymington
1884. ‡Chipman, W W L 957 Dorchester-street, Montreal, Canada
1894. ‡CHISHOLM, G G, M A, B Sc, F R G S (Pres E, 1907) 12 Hallhead-road, Edinburgh
1899 §Chitty, Edward Sonnenberg, Castle-avenue, Dover
1899 ‡Chitty, Mrs Edward Sonnenberg, Castle-avenue, Dover.
1904 §Chivers, John, J.P. Wychfield, Cambridge
1882. ‡Chorley, George Midhurst, Sussex
1909. ‡Chow, H. H., M D 263 Broadway, Winnipeg, Canada.
1893 *CHREE, CHARLES, D Sc, F R S Kew Observatory, Richmond, Surrey.
1900. *Christie, R J Duke-street, Toronto, Canada
1875. *Christopher, George, F C S. Thornycroft, Chislehurst
1870. §CHURCH, Sir ARTHUR, K C V O, M A, F R S, F S A Shelsley, Ennerdale-road, Kew
1903. ‡Clapham, J H, M A King's College, Cambridge.
1901. §Clark, Archibald B, M.A., Professor of Political Economy in the University of Manitoba, Winnipeg, Canada.
1905. *Clark, Cumberland, F R G S 29 Chepstow-villas, Bayswater, W.
1907. *Clark, Mrs Cumberland. 29 Chepstow-villas, Bayswater, W.
1877. *Clark, F J., J P, F L S Netherleigh, Street, Somerset
1902 ‡Clark, G M South African Museum, Cape Town
1908. ‡Clark, James, B Sc Newtown School, Waterford, Ireland.
1881. *Clark, J. Edmund, B.A, B Sc. Asgarth, Riddlesdown road, Purley, Surrey.

Year of Election

1909. §Clark, J. M., M.A , K.C. The Kent Building, 156 Yonge-street, Toronto, Canada

1908 §Clark, John R W. Brothock Bank House, Arbroath, Scotland.

1901. *Clark, Robert M , B Sc., F L S 27 Albyn-place, Aberdeen.

1907 *Clarke, E Russell 11 King's Bench-walk, Temple, E C.

1902. *CLARKE, Miss LILIAN J., B Sc., F.L.S. Chartfield Cottage, Brasted Chart, Kent.

1889. *CLAYDEN, A W , M A , F G S 5 The Crescent, Mount Radford, Exeter.

1908. *Clayton, Miss Edith M. Brackendene, Horsell, Surrey.

1909. §Cleeves, Frederick, F Z.S. 23 Lime-street, E.C.

1909. ‡Cleeves, W. B. Public Works Department, Government-buildings, Pretoria.

1861. ‡CLELAND, JOHN, M.D , D Sc , F R S Drumclog, Crewkerne, Somerset.

1905 §Cleland, Mrs Drumclog, Crewkerne, Somerset.

1905 §Cleland, J R Drumclog, Crewkerne, Somerset.

1902. ‡Clements, Olaf P Tana, St Bernard's-road, Olton, Warwick

1904. §CLERK, Dr DUGALD, F R S , M Inst C E (Pres G, 1908 , Council 1912-) 57 and 58 Lincoln's Inn Fields, W C.

1909. ‡Cleve, Miss E. K. P. 74 Kensington Gardens-square, W.

1861 *CLIFTON, R BELLAMY, M A , F R S , F R A S , Professor of Experimental Philosophy in the University of Oxford 3 Bardwell-road, Banbury-road, Oxford

1906 §CLOSE, Colonel C F , R E , C M G , F R G S (Pres. E, 1911 , Council, 1908–12) Army and Navy Club, Pall Mall, S.W

1883. *CLOWES, FRANK, D Sc , F C S (Local Sec 1893.) The Grange, College-road, Dulwich, S E

1912 §Clubb, Joseph A , D Sc Free Public Museum, Liverpool

1891. *Coates, Henry, F R S E Balure, Perth

1884 ‡Cobb, John Fitzharris, Abingdon

1911. §Cobbold, E S , F G S Church Stretton, Shropshire

1908. *Cochrane, Miss Constance The Downs, St Neots

1864. *Cochrane, James Henry Burston House, Pittville, Cheltenham

1908 ‡Cochrane, Robert, I S O , LL D , F S A. 17 Highfield-road, Dublin

1901. ‡Cockburn, Sir John, K C M G , M D 10 Gatestone-road, Upper Norwood, S E

1883. ‡Cockshott, J. J 24 Queen's-road, Southport

1861. *Coe, Rev Charles C , F R G S. Whinsbridge, Grosvenor-road, Bournemouth

1908. ‡*Coffey, Denis J., M B. 2 Arkendale-road, Glenageary, Co Dublin.*

1898 ‡Coffey, George 5 Harcourt-terrace, Dublin

1881. *COFFIN, WALTER HARRIS, F.C S Passaic, Kew

1896. *Coghill, Percy de G. 4 Sunnyside, Prince's Park, Liverpool.

1901. §Cohen, N L 11 Hyde Park-terrace, W

1901. *Cohen, R Waley, B A. 11 Sussex-square, W.

1906. *Coker, Professor Ernest George, M A , D Sc., F R S.E. City and Guilds of London Technical College, Finsbury, E.C.

1895 *Colby, James George Ernest, M A., F R C S. Malton, Yorkshire.

1895. *Colby, William Henry Carregwen, Aberystwyth.

1893. §COLE, GRENVILLE A J , F G S , Professor of Geology in the Royal College of Science, Dublin

1903. ‡Cole, Otto B 551 Boylston-street, Boston, U S.A.

1910. §Cole, Thomas Skelton. Westbury, Endcliffe-crescent, Sheffield.

1897. §COLEMAN, Professor A. P , M.A., Ph.D., F.R.S. (Pres. C, 1910.) 476 Huron-street, Toronto, Canada.

Year of Election

1899. ‡Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1912. §Collett, J. M., J.P. Kimsbury House, Gloucester
1887. ‡COLLIE, J. NORMAN, Ph.D., F.R.S., Professor of Organic Chemistry in the University of London. 16 Campden-grove, W.
1893. ‡Collinge, Walter E. The University, Birmingham.
1861. *Collingwood, J. Frederick, F.G.S. 5 Irene-road, Parson's Green, S.W.
1876. ‡COLLINS, J. H., F.G.S. Crinnis House, Par Station, Cornwall.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1910. *Collins, S. Hoare. 9 Cavendish-place, Newcastle-on-Tyne.
1902. ‡Collins, T. R. Belfast Royal Academy, Belfast.
1910. *Colver, Robert, jun. Graham-road, Ranmoor, Sheffield.
1905. *Combs, Rev. Cyril W., M.A. Elverton, Castle-road, Newport, Isle of Wight.
1910. *Compton, Robert Harold, B.A. Gonville and Caius College, Cambridge.
1912. §Conner, William. Cooleen, Queenstown, Ireland.
1871. *Connor, Charles C. 10 College-gardens, Belfast.
1902. ‡Conway, A. W. 100 Leinster-road, Rathmines, Dublin.
1903. ‡Conway, R. Seymour, Litt.D., Professor of Latin in Owens College, Manchester.
1898. §Cook, Ernest H., D.Sc. 27 Berkeley-square, Clifton, Bristol.
1913. §Cook, Gilbert, M.Sc., Assoc.M.Inst.C.E. Engineering Department, The University, Manchester.
1876. *COOKE, CONRAD W. The Pines, Langland-gardens, Hampstead, N.W.
1911. §Cooke, J. H. 101 Victoria-road North, Southsea.
1888. ‡Cooley, George Parkin. Constitutional Club, Nottingham.
1899. *Coomaraswamy, A. K., D.Sc., F.L.S., F.G.S. Broad Campden, Gloucestershire.
1902. *Coomaraswamy, Mrs. A. K. Broad Campden, Gloucestershire.
1903. §Cooper, Miss A. J. 22 St. John-street, Oxford.
1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1911. §Cooper, W. E. Henwick Lodge, Worcester.
1912. §Cooper, W. F. The Laboratory, Rickmansworth-road, Woodford.
1907. ‡Cooper, William. Education Offices, Becket-street, Derby.
1904. *COPEMAN, S. MONCKTON, M.D., F.R.S. Local Government Board, Whitehall, S.W.
1909. §Copland, Mrs. A. J. Gleniffer, 50 Woodberry Down, N.
1904. *Copland, Miss Louisa. 10 Wynnstay-gardens, Kensington, W.
1909. §Corbett, W. A. 207 Bank of Nova Scotia-building, Winnipeg, Canada.
1887. *Corcoran, Bryan. 23 Croham Park-avenue, South Croydon.
1894. §Corcoran, Miss Jessie R. Rotherfield Cottage, Bexhill-on-Sea.
1901. *Cormack, Professor J. D., D.Sc. University College, Gower-street, W.C.
1893. *Corner, Samuel, B.A., B.Sc. Abbotsford House, Waverley-street, Nottingham.
1889. ‡CORNISH, VAUGHAN, D.Sc., F.R.G.S. Royal Colonial Institute, Northumberland-avenue, W.C.
1884. *Cornwallis, F. S. W., F.L.S. Linton Park, Maidstone.
1900. §CORTIE, Rev. A. L., S.J., F.R.A.S. Stonyhurst College, Blackburn.
1905. ‡Cory, Professor G. E., M.A. Rhodes University College, Grahamstown, Cape Colony.
1909. *Cossar, G. C., M.A., F.G.S. Southview, Murrayfield, Edinburgh.
1910. §Cossar, James. 53 Belford-road, Edinburgh.
1911. ‡Cossey, Miss, M.A. High School for Girls, Kent-road, Southsea.
1908. *Costello, John Francis, B.A. The Rectory, Ballymackey, Nenagh, Ireland.

Year of Election

1906. ‡Cotsworth, Moses B. Acomb, York
1874 *COTTERILL, J H, M A, F R S. Boleskine, Branksome Park, Bournemouth.
1908. ‡Cotton, Alderman W F, D L, J P, M P. Hollywood, Co. Dublin.
1908 ‡Courtenay, Colonel Arthur H, C B, D L. United Service Club, Dublin
1896 ‡COURTNEY, Right Hon Lord (Pres F, 1896) 15 Cheyne-walk, Chelsea, S W
1905 ‡Cousens, R L P O Box 4261, Johannesburg
1911. ‡Couzens, Sir G E, K L H Glenthorne, Kingston-crescent, Portsmouth
1908 ‡Cowan, P C, B Sc, M Inst C E 33 Ailesbury-road, Dublin
1872 *Cowan, Thomas William, F L S, F G S Upcott House, Taunton, Somersetshire
1903 ‡Coward, H Knowle Board School, Bristol
1900. §Cowburn, Henry Dingle Head, Leigh, Lancashire
1895 *COWELL, PHILIP H, M A, D Sc, F R S 62 Shooters Hill-road, Blackheath, S E
1899. ‡Cowper-Coles, Sherard 1 and 2 Old Pye-street, Westminster, S.W.
1867 *Cox, Edward Cardean, Meigle, N B
1909. ‡Cox, F. J. C. Anderson-avenue, Winnipeg, Canada.
1906 ‡*Cox, S Herbert, Professor of Mining in the Imperial College of Science and Technology, S W.*
1905. ‡Cox, W H Royal Observatory, Cape Town
1912 §Craig, D D, M A, B Sc, M B. The University, St. Andrews, N B
1908 ‡Craig, James, M D 18 Merrion-square North, Dublin.
1911. §Craig, J I Homelands, Park-avenue, Worthing
1884 §CRAIGIE, Major P G, C B, F S S (Pres F, 1900, Council, 1908–) Brontë House, Lympstone, Devon.
1906 ‡Craik, Sir Henry, K C B, LL.D, M P 5A Dean's-yard, Westminster, S W
1908 *Cramer, W, Ph D, D Sc Physiological Department, The University, Edinburgh
1906 ‡Cramp, William Redthorn, Whalley-road, Manchester
1905. **Cranswick, Wm. Franceys 34 Boshof-road, Kimberley*
1906 ‡CRAVEN, HENRY (Local Sec 1906) Clifton Green, York.
1905 ‡Crawford, Mrs A M Marchmont, Rosebank, near Cape Town.
1910. *Crawford, O G S. The Grove, East Woodhay, Newbury.
1905 ‡Crawford, Professor Lawrence, M A, D Sc, F R S E. South African College, Cape Town
1871. *Crawford, William Caldwell, M A 1 Lockharton-gardens, Colinton-road, Edinburgh
1905. ‡Crawford, W C, jun 1 Lockharton-gardens, Colinton-road, Edinburgh.
1871. *CRAWFORD AND BALCARRES, The Right Hon the Earl of, K.T, LL.D, F R S., F R A S 2 Cavendish-square, W; and Haigh Hall, Wigan
1890. §Crawshaw, Charles B Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward. F R G S 25 Tollington-park, N.
1885. §CREAK, Captain E. W., C B, R.N., F.R.S. (Pres. E, 1903; Council, 1896–1903) 9 Hervey-road, Blackheath, S E.
1876. *Crewdson, Rev. Canon George. Whitstrav, Cambridge.
1887. *Crewdson, Theodore. Spurs, Styall, Handforth, Manchester.
1911. ‡Crick, George C, F.G.S. British Museum (Natural History), S.W.
1904. ‡Crilly, David. 7 Well-street, Paisley.

Year of Election

1880. *Crisp, Sir Frank, Bart , B A , LL B , F L S , F.G S. 5 Lansdowne-road Notting Hill, W.
1908. §Crocker, J Meadmore Albion House, Bingley, Yorkshire.
1905. §Croft, Miss Mary Quedley, Shottermill
1890 *Croft, W B , M A Winchester College, Hampshire
1908 ‡Crofts, D. G Cadastral Survey, Nairobi, British East Africa.
1878. *Croke, John O'Byrne, M A Clouncagh, Ballingarry-Lacy, Co. Limerick.
1903. *Crompton, Holland Oaklyn, Cross Oak-road, Berkhamsted.
1901. ‡CROMPTON, Colonel R E , C B , M Inst C E (Pres. G, 1901) Kensington-court, W.
1887. ‡CROOK, HENRY T , M Inst C E Lancaster-avenue, Manchester.
1898 §CROOKE, WILLIAM, B.A (Pres H, 1910 ; Council, 1910– .) Langton House, Charlton Kings, Cheltenham
1865 §CROOKES, Sir WILLIAM, O M., D Sc , F R S , V P C S (PRESIDENT, 1898 ; Pres B, 1886 ; Council, 1885-91) 7 Kensington Park gardens, W
1879 ‡Crookes, Lady 7 Kensington Park gardens, W
1897. *CROOKSHANK, E M , M B Saint Hill, East Grinstead, Sussex.
1909. ‡Crosby, Rev. E. H. Lewis, B.D 36 Rutland-square, Dublin.
1905 ‡Crosfield, Hugh T Walden, Coombe-road, Croydon.
1894. *Crosfield, Miss Margaret C Undercroft, Reigate
1870. *CROSFIELD, WILLIAM 3 Fulwood-park, Liverpool
1904 §Cross, Professor Charles R Massachusetts Institute of Technology, Boston, U S A.
1890 ‡Cross, E Richard, LL B Harwood House, New Parks-crescent, Scarborough
1905 §Cross, Robert 13 Moray-place, Edinburgh
1904 *CROSSLEY, A W , D Sc , Ph D , F R S , Professor of Chemistry to the Pharmaceutical Society of Great Britain 10 Crediton-road, West Hampstead, N W
1908 ‡Crossley, F W 30 Molesworth street, Dublin
1897 *Crosweller, Mrs W T Kent Lodge, Sidcup, Kent
1890 *Crowley, Ralph Henry, M D Sollershott W Letchworth.
1910. §Crowther, Dr. C , M A The University, Leeds
1910 *Crowther, James Arnold St John's College, Cambridge.
1911 §Crush, S. T. Care of Messrs Yarrow & Co , Ltd , Scotstoun West, Glasgow.
1883 *CULVERWELL, EDWARD P , M A , Professor of Education in Trinity College, Dublin
1883 ‡Culverwell, T J H Litfield House, Clifton, Bristol.
1911. §Cumming, Alexander Charles, D Sc Chemistry Department, University of Edinburgh
1911. §Cummins, Major H A , M D , C M.G , Professor of Botany in University College, Cork
1898 ‡Cundall, J. Tudor 1 Dean Park-crescent, Edinburgh.
1861. *Cunliffe, Edward Thomas The Parsonage, Handforth, Manchester
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1905. ‡Cunningham, Miss A. 2 St Paul's-road, Cambridge.
1882. *CUNNINGHAM, Lieut -Colonel ALLAN, R.E., A I C E 20 Essex villas, Kensington, W
1905. ‡Cunningham, Andrew. Earlsferry, Campground-road, Mowbray, South Africa
1911. ‡Cunningham, E St John's College, Cambridge.
1885. ‡CUNNINGHAM, J. T , B A Biological Laboratory, Plymouth.
1869. ‡CUNNINGHAM, ROBERT O , M D , F L S , Professor of Natural History in Queen's College, Belfast

Year of Election

1883. *CUNNINGHAM, Ven. W., D D., D.Sc. (Pres. F, 1891, 1905.) Trinity College, Cambridge.
1892. ‡*Cunningham-Craig, E H., B.A., F.G.S.* 14A *Dublin-street, Edinburgh.*
1900 *Cunnington, William A, M A, Ph D, F.Z S. 25 Orlando-road, Clapham Common, S W
1912 §CUNYNGHAME, Sir HENRY H., K.C B (Pres. F, 1912.) Home Office, S.W.
1908. ‡Currelly, C T, M A, F R G.S. United Empire Club, 117 Piccadilly, W.
1892. *Currie, James, M A, F R S E Larkfield, Wardie-road, Edinburgh.
1905. ‡Currie, Dr O J. Manor House, Mowbray, Cape Town.
1905 ‡Currie, W P P O Box 2010, Johannesburg
1902 ‡Curry, Professor M, M Inst C E 5 King's-gardens, Hove
1912 §Curtis, Charles Field House, Cainscross, Stroud, Gloucestershire.
1883 ‡Cushing, Mrs M Rosslynlee, Woodside Green, South Norwood, S E
1881 §Cushing, Thomas, F R A S Rosslynlee, Woodside Green, South Norwood, S E.
1907. ‡CUSHNY, ARTHUR R, M D, F R S, Professor of Pharmacology in University College, Gower-street, W C.

1910. §Dakin, Dr W J. The University, Liverpool.
1898 *DALBY, W E, M A, B Sc, M Inst C E (Pres. G, 1910), Professor of Civil and Mechanical Engineering in the City and Guilds of London Institute, Exhibition-road, S W
1889. *Dale, Miss Elizabeth Garth Cottage, Oxford-road, Cambridge.
1906. §Dale, William, F S A, F G S The Lawn, Archer's-road, Southampton
1907. ‡DALGLIESH, RICHARD, J P, D.L Ashfordby Place, near Melton Mowbray
1904 *DALTON, J H C, M D The Plot, Adams-road, Cambridge.
1862 ‡DANBY, T W, M A, F G S The Crouch, Seaford, Sussex.
1905 ‡Daniel, Miss A M 3 St John's-terrace, Weston-super-Mare
1901. *DANIELL, G F, B Sc Woodberry, Oakleigh Park, N.
1896. §Danson, F C Tower-buildings, Water-street, Liverpool.
1849 *Danson, Joseph Montreal, Canada
1897. ‡Darbishire, F. V, B A, Ph D. Dorotheenstrasse 12, Dresden 20
1903 §Darbishire, Dr Otto V. Armstrong College, Newcastle-on-Tyne.
1904. *Darwin, Charles Galton Newnham Grange, Cambridge
1899. *Darwin, Erasmus The Orchard, Huntingdon-road, Cambridge.
1882 *DARWIN, SIR FRANCIS, M A, M.B, LL.D, D.Sc, F.R S, F.L.S. (PRESIDENT, 1908; Pres D, 1891; Pres K, 1904; Council, 1882–84, 1897–1901.) 10 Madingley-road, Cambridge
1905. ‡Darwin, Lady Newnham Grange, Cambridge
1878. *DARWIN, HORACE, M.A., F R S The Orchard, Huntingdon-road, Cambridge.
1894. *DARWIN, Major LEONARD, F R.G S (Pres E, 1896; Council, 1899–1905) 12 Egerton-place, South Kensington, S W.
1882. ‡Darwin, W. E, B A, F.G S 11 Egerton-place, S.W.
1910. §Dauncey, Mrs. Thursby. Lady Stewert, Heath-road, Weybridge.
1908. ‡Davey, H 15 Victoria-road, Brighton.
1880. *DAVEY, HENRY, M.Inst C.E. Conaways, Ewell, Surrey.
1884. ‡David, A. J., B.A, LL.B 4 Harcourt-buildings, Temple, E.C.
1904. §Davidge, H. T., B Sc., Professor of Electricity in the Ordnance College, Woolwich

Year of Election.

1909. ‡Davidson, A. R. 150 Stradbrooke-place, Winnipeg, Canada.
1912. §Davidson, Rev J. The Manse, Douglas, Isle of Man
1912. §Davidson, John, M A, D Ph. Training College, Small's Wynd, Dundee.
1902 *Davidson, S C Seacourt, Bangor, Co Down.
1910. *Davie, Robert C., M.A., B Sc 16 Ruthven-street, Kelvinside, Glasgow.
1887. *Davies, H Rees Treborth, Bangor, North Wales.
1904. §Davies, Henry N, F G S. St Chad's, Weston-super-Mare.
1906. ‡Davies, S H. Ryecroft, New Earswick, York.
1893. *Davies, Rev. T. Witton, B A, Ph D, D D., Professor of Semitic Languages in University College, Bangor, North Wales
1896. *Davies, Thomas Wilberforce, F G S 41 Park-place, Cardiff
1870. *Davis, A S St George's School, Roundhay, near Leeds
1873. *Davis, Alfred 37 Ladbroke-grove, W
1896. *Davis, John Henry Grant. Dolobran, Wood Green, Wednesbury
1910. ‡Davis, John King. 2 Brockenhurst Green-street, Jersey.
1905. §Davis, Luther P O. Box 898, Johannesburg.
1885. *Davis, Rev Rudolf Mornington, Elmbridge-road, Gloucester
1912. §Dawkins, Miss Ella Boyd Fallowfield House, Fallowfield, Manchester
1864 ‡Dawkins, W Boyd, D Sc, F R S, F S A, F G S (Pres C, 1888; Council, 1882–88) Fallowfield House, Fallowfield, Manchester
1885. *Dawson, Lieut-Colonel H P, R A Hartlington Hall, Burnsall, Skipton-in-Craven
1901. *Dawson, P The Acre, Maryhill, Glasgow
1905. ‡Dawson, Mrs. The Acre, Maryhill, Glasgow
1884. ‡Dawson, Samuel (Local Sec 1884) 258 University-street Montreal, Canada
1912. *Dawson, Shepherd, M A, B Sc Drumchapel, near Glasgow
1906 §Dawson, William Clarke Whitefriargate, Hull.
1859. *Dawson, Captain W. G. Abbots Morton, near Worcester.
1909. ‡Day, Miss M. Edith. 290 Portage-avenue, Winnipeg, Canada.
1900. ‡Deacon, M. Whittington House, near Chesterfield
1909. §Dean, George, F R.G S. 5 Wordsworth-mansions, Queen's Club-gardens, W.
1901 *Deasy, Captain H H P. Cavalry Club, 127 Piccadilly, W
1884. *Debenham, Frank, F S S 1 Fitzjohn's-avenue, N W
1866. ‡Debus, Heinrich, Ph D, F R S, F C S (Pres B, 1869; Council, 1870–75) 4 Schlangenweg, Cassel, Hessen
1893. *Deeley, R M, M Inst C E, F G S Abbeyfield, Salisbury-avenue, Harpenden, Herts
1911. ‡Delahunt, C G The Municipal College, Portsmouth
1878. ‡Delany, Very Rev. William, LL D University College, Dublin.
1908. *Delf, Miss E M Westfield College, Hampstead, N W
1907. ‡De Lisle, Mrs Edwin. Charnwood Lodge, Coalville, Leicestershire
1896. ‡Dempster, John Tynron, Noctorum, Birkenhead
1902. *Dendy, Arthur, D Sc, F R S, F L S (Council, 1912–), Professor of Zoology in King's College, London, W C
1908. ‡Dennehy, W. F. 23 Leeson-park, Dublin
1889. §Denny, Alfred, M.Sc., F L S., Professor of Biology in the University of Sheffield.
1909. §Dent, Edward, M.A. 2 Carlos-place, W.
1874. *Derham, Walter, M.A, LL.M., F G S. Junior Carlton Club, Pall Mall, S.W.
1907. *Desch, Cecil H., D.Sc., Ph.D. 9 Spring-gardens, North Kelvinside, Glasgow.

Year of Election.

1908. §Despard, Miss Kathleen M. 6 Sutton Court-mansions, Grove Park-terrace, Chiswick, W.
1894 *Deverell, F. H. 7 Grote's-place, Blackheath, S E.
1868. *Dewar, Sir James, M A , LL D , D Sc , F R S , F.R S E , V P C.S , Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge (President, 1902 ; Pres. B, 1879 ; Council, 1883–88.) 1 Scroope-terrace, Cambridge
1881. ‡Dewar, Lady 1 Scroope-terrace, Cambridge
1884 *Dewar, William, M A Horton House, Rugby
1908 §Dicks, Henry Haslecourt, Horsell, Woking
1904. ‡Dickson, Right Hon Charles Scott, K C , LL D , M.P. Carlton Club, Pall Mall, S W.
1881. ‡Dickson, Edmund, M A , F G S Claughton House, Garstang, R S O , Lancashire
1887. §Dickson, H N , D Sc , F R S E , F R G S , Professor of Geography in University College, Reading The Lawn, Upper Redlands-road, Reading
1902 §Dickson, James D Hamilton, M A , F R S E 6 Cranmer-road, Cambridge
1877 ‡Dillon, James, M Inst C E. 36 Dawson-street, Dublin
1908. ‡Dines, J. S. Pyrton Hill, Watlington.
1901. §Dines, W H , B.A , F R S Pyrton Hill, Watlington.
1898 *Dix, John William S Hampton Lodge, Durdham Down, Clifton, Bristol
1905 §Dixey, F A , M A , M D , F R S. Wadham College, Oxford
1899 *Dixon, A C , D Sc , F R S , Professor of Mathematics in Queen's University, Belfast Hurstwood, Malone Park, Belfast.
1874. *Dixon, A. E , M D , Professor of Chemistry in University College, Cork
1900 ‡Dixon, A Francis, Sc D , Professor of Anatomy in the University of Dublin
1905 ‡Dixon, Miss E K Fern Bank, St Bees, Cumberland
1908 ‡Dixon, Edward K , M E , M Inst C E Castlebar, Co Mayo
1888 ‡Dixon, Edward T Racketts, Hythe, Hampshire
1908. *Dixon, Ernest, B Sc , F.G S. The Museum, Jermyn-street, S.W.
1900 *Dixon, Lieut.-Colonel George, M A Fern Bank, St. Bees, Cumberland
1879 *Dixon, Harold B , M A , F R S , F C S (Pres B, 1894), Professor of Chemistry in the Victoria University, Manchester
1902 ‡Dixon, Henry H , D Sc , F R S , Professor of Botany in the University of Dublin Clevedon, Temple-road, Dublin
1913 §Dixon, S M , M A , M Inst C E., Professor of Civil Engineering in the University of Birmingham The University, Edgbaston, Birmingham
1908 *Dixon, Walter, F R M S. Derwent, 30 Kelvinside-gardens, Glasgow
1907. *Dixon, Professor Walter E , F.R S. The Museums, Cambridge.
1902 ‡Dixon, W V Scotch Quarter, Carrickfergus
1896. §Dixon-Nuttall, F. R Ingleholme, Eccleston Park, Prescot.
1890 ‡Dobbie, James J , D Sc , LL.D., F R S , Principal of the Government Laboratories, 13 Clement's Inn-passage, W.C.
1885. §Dobbin, Leonard, Ph.D The University, Edinburgh
1860. *Dobbs, Archibald Edward, M A. Castle Dobbs, Carrickfergus, Co. Antrim.
1902. ‡Dobbs, F W. 2 Willowbrook, Eton, Windsor
1908. ‡Dodd, Hon Mr. Justice. 26 Fitzwilliam-square, Dublin.

Year of Election

1876. ‡Dodds, J M St Peter's College, Cambridge.
1912. §Don, A W. R. The Lodge, Broughty Ferry, Forfarshire
1912. §Don, Alexander, M.A , F R C S Park House, Nethergate, Dundee.
1912. §Don, Robert Bogle, M A The Lodge, Broughty Ferry, Forfarshire.
1904. ‡Doncaster, Leonard, M.A Museum of Zoology, Cambridge
1896 ‡Donnan, F E. Ardenmore-terrace, Holywood, Ireland.
1901. ‡Donnan, F G , M A , Ph D , F R S , Professor of Chemistry in the University of London
1905 ‡*Donner, Arthur. Helsingfors, Finland.*
1905. §Dornan, Rev. S. S. P.O. Box 510, Bulawayo, South Rhodesia, South Africa
1863. *Doughty, Charles Montagu 26 Grange-road, Eastbourne
1909. ‡Douglas, A. J , M.D. City Health Department, Winnipeg, Canada.
1909 *Douglas, James 99 John-street, New York, U S A
1912. §Doune, Lord Kinfauns Castle, Perth
1884. ‡Dove, Miss Frances Wycombe Abbey School, Buckinghamshire
1903. ‡Dow, Miss Agnes R 81 Park-mansions, Knightsbridge, S W.
1884. *Dowling, D J. Sycamore, Clive-avenue, Hastings
1865. *Dowson, E Theodore, F R M S Geldeston, near Beccles, Suffolk.
1881. *Dowson, J Emerson, M Inst C E 26 Egerton-crescent, S W
1892 *Dreghorn, David, J P Greenwood, Pollokshields, Glasgow
1912. §Drever, James, M A , B Sc 32 Lomond-road, Trinity, Edinburgh.
1905. ‡Drew, H. W , M B , M R C S Mocollup Castle, Ballyduff, S O. Co. Waterford
1906. *Drew, Joseph Webster, M A , LL M Fashoda, Scarborough
1906 *Drew, Mrs Fashoda, Scarborough
1908 ‡Droop, J P 11 Cleveland-gardens, Hyde Park, W
1893. §Druce, G Claridge, M A , F L S (Local Sec 1894.) Yardley Lodge, 9 Crick-road, Oxford
1909. *Drugman, Julien, Ph D , M Sc 117 Rue Gachard, Brussels
1907. ‡Drysdale, Charles V , D Sc Northampton Institute, Clerkenwell, E C
1892. ‡Du Bois, Professor Dr H Herwarthstrasse 4, Berlin, N W.
1856. *Ducie, The Right Hon Henry John Reynolds Moreton, Earl of, F R S , F G S 16 Portman-square, W
1870. ‡Duckworth, Henry, F L S , F G S 7 Grey Friars, Chester
1900. *Duckworth, W L H , M D , Sc D Jesus College, Cambridge
1895. *Duddell, William, F.R S 47 Hans-place, S W
1906. ‡Dudgeon, Gerald C , Superintendent of Agriculture for British West Africa Bathurst, Gambia, British West Africa
1904 *Duffield, Professor W Geoffrey, D Sc University College Reading
1890 ‡Dufton, S F. Trinity College, Cambridge
1911. ‡Dummer, John 85 Cottage-grove, Southsea
1909. ‡Duncan, D. M., M A 83 Spence-street, Winnipeg, Canada.
1891. *Duncan, Sir John, J.P 'South Wales Daily News' Office, Cardiff
1910. ‡Dunn, Rev. J. Road Hill Vicarage, Bath
1876 ‡Dunnachie, James 48 West Regent-street, Glasgow.
1884 §Dunnington, Professor F P University of Virginia, Charlottesville, Virginia, U S.A.
1893 *Dunstan, M. J R., Principal of the South-Eastern Agricultural College, Wye, Kent.
1891. ‡Dunstan, Mrs South-Eastern Agricultural College, Wye, Kent
1885. *Dunstan, Wyndham R., C.M.G , M.A., LL D , F R S , F.C S (Pres. B, 1906 , Council, 1905–08), Director of the Imperial Institute, S.W.

Year of Election

1911. ‡Dupree, Colonel Sir W. T. Craneswater, Southsea.
1905. §Dutton, C. L. O'Brien. High Commissioner's Office, Johannesburg.
1910. §Dutton, F. V., B.Sc. County Agricultural Laboratories, Richmond-road, Exeter.
1895. *Dwerryhouse, Arthur R., D.Sc., F.G.S. Deraness, Deramore Park, Belfast.
1911. §Dye, Charles. Woodcrofts, London-road, Portsmouth.
1885. *Dyer, Henry, M.A., D.Sc., LL.D. 8 Highburgh-terrace, Dowanhill, Glasgow.
1895. §Dymond, Thomas S., F.C.S. Savile Club, Piccadilly, W.
1905. *Dyson, F. W., M.A., F.R.S. (Council, 1905–11), Astronomer Royal, Royal Observatory, Greenwich, S.E.
1910. ‡Dyson, W. H. Maltby Colliery, near Rotherham, Yorkshire.

1912. §Earland, Arthur, F.R.M.S. 34 Granville-road, Watford.
1899. ‡East, W. H. Municipal School of Art, Science, and Technology, Dover.
1909. *Easterbrook, C. C., M.A., M.D. Crichton Royal Institution, Dumfries.
1893. *Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1906. *Ebbs, Mrs. A. B. Tuborg, Plaistow-lane, Bromley, Kent.
1909. ‡Eccles, J. R. Gresham's School, Holt, Norfolk.
1903. ‡Eccles, W. H., D.Sc. 37 Chelsea-gardens, Chelsea Bridge-road, S.W.
1908. *Eddington, A. S., M.A., M.Sc. Royal Observatory, Greenwich, S.E.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
1858. *Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1911. *Edge, S. F. 14 New Burlington-street, W.
1911. *Edgell, Miss Beatrice, Bedford College, Baker street, W.
1884. *Edgell, Rev. R. Arnold, M.A. Beckley Rectory, East Sussex.
1887. §Edgeworth, F. Y., M.A., D.C.L., F.S.S. (Pres. F, 1889; Council, 1879–86, 1891–98), Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Clement's Inn, W.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.
1901. *Edridge-Green, F. W., M.D., F.R.C.S. 99 Walm-lane, Willesden Green, N.W.
1899. §Edwards, E. J., Assoc.M.Inst.C.E. 90 Earlsfield-road, Wandsworth Common, S.W.
1903. ‡Edwards, Mrs. Emily. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Francis. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Miss Marion K. Norley Grange, 73 Leyland-road, Southport.
1901. ‡Eggar, W. D. Eton College, Windsor.
1909. ‡Eggertson, Arni. 120 Emily-street, Winnipeg, Canada.
1909. §Ehrenborg, G. B. 63 Fairfield-building, Vancouver, B.C., Canada.
1907. *Elderton, W. Palin. 74 Mount Nod-road, Streatham, S.W.
1890. §Elford, Percy. 115 Woodstock-road, Oxford.
1901. *Elles, Miss Gertrude L., D.Sc. Newnham College, Cambridge.
1904. ‡Elliot, Miss Agnes I. M. Newnham College, Cambridge.
1904. ‡Elliot, R. H. Clifton Park, Kelso, N.B.
1891. ‡Elliott, A. C., D.Sc., M.Inst.C.E., Professor of Engineering in University College, Cardiff. 2 Plasturton-avenue, Cardiff.
1905. ‡Elliott, C. C., M.D. Church-square, Cape Town.

Year of Election

1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.

Elliott, John Fogg. Elvet Hill, Durham.

1912. §Elliott, Dr. W. F., F.Z.S. 65 Temple-row, Birmingham.

1906. *Ellis, David, D.Sc., Ph.D. Technical College, Glasgow.

1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.

1906. §ELLIS, HERBERT. 120 Regent-road, Leicester.

1880. *ELLIS, JOHN HENRY. (Local Sec. 1883.) 10 The Crescent, Plymouth.

1891. §Ellis, Miss M. A. 14 Wellington-square, Oxford.

1906. ‡ELMHIRST, CHARLES E. (Local Sec. 1906.) 29 Mount-vale, York.

1910. §Elmhirst, Richard. Marine Biological Station, Millport.

1911. ‡Elwes, H. J., F.R.S. Colesbourne Park, near Cheltenham.

1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.

1869. *Enys, John Davies. Enys, Penryn, Cornwall.

1894. ‡Erskine-Murray, J., D.Sc., F.R.S.E. Oswaldestre House, 34 Norfolk-street, W.C.

1862. *ESSON, WILLIAM, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.

1887. *Estcourt, Charles, F.I.C. 5 Seymour-grove, Old Trafford, Manchester.

1887. *Estcourt, P. A., F.C.S., F.I.C. 5 Seymour-grove, Old Trafford, Manchester.

1911. ‡ETHERTON, G. HAMMOND. (Local Sec., 1911.) Town Hall, Portsmouth.

1897. *Evans, Lady. Britwell, Berkhamsted, Herts.

1889. *EVANS, A. H., M.A. 9 Harvey-road, Cambridge.

1905. ‡Evans, Mrs. A. H. 9 Harvey-road, Cambridge.

1870. *EVANS, Sir ARTHUR JOHN, M.A., LL.D., F.R.S., F.S.A. (Pres. H, 1896.) Youlbury, Abingdon.

1908. ‡Evans, Rev. Henry, D.D., Commissioner of National Education, Ireland. Blackrock, Co. Dublin.

1887. *Evans, Mrs. Isabel. Hoghton Hall, Hoghton, near Preston.

1883. *Evans, Mrs. James C. Casewell Lodge, Llanwrtyd Wells, South Wales.

1910. *EVANS, JOHN W., D.Sc., LL.B., F.G.S. 75 Craven Park-road, Harlesden, N.W.

1885. *Evans, Percy Bagnall. The Spring, Kenilworth.

1905. ‡Evans, R. O. Ll. Broom Hall, Chwilog, R.S.O., Carnarvonshire.

1905. ‡Evans, T. H. 9 Harvey-road, Cambridge.

1910. ‡Evans, T. J. The University, Sheffield.

1865. *Evans, William. The Spring, Kenilworth.

1909. ‡EVANS, W. SANFORD, M.A. (Local Sec. 1909.) 43 Edmonton-street, Winnipeg.

1903. ‡*Evatt, E. J., M.B.* 8 *Kyveilog-street, Cardiff.*

1902. *Everett, Percy W. Oaklands, Elstree, Hertfordshire.

1883. ‡Eves, Miss Florence. Uxbridge.

1881. ‡EWART, J. COSSAR, M.D., F.R.S. (Pres. D, 1901), Professor of Natural History in the University of Edinburgh.

1874. ‡EWART, Sir W. QUARTUS, Bart. (Local Sec. 1874.) Glenmachan, Belfast.

1876. *EWING, Sir JAMES ALFRED, K.C.B., M.A., LL.D., F.R.S., F.R.S.E., M.Inst.C.E. (Pres. G, 1906), Director of Naval Education, Admiralty, S.W. Froghole, Edenbridge, Kent.

1903. §Ewing, Peter, F.L.S. The Frond, Uddingston, Glasgow.

Year of Election.

1884. *Eyerman, John, F.Z S Oakhurst, Easton, Pennsylvania, U.S.A.
1912. §Eyre, J. Vargas. 26 Bridge-road West, Battersea Park, S.W.
Eyton, Charles. Hendred House, Abingdon.

1906 *Faber, George D 14 Grosvenor-square, W.
1901. *Fairgrieve, M McCallum. 37 Queen's-crescent, Edinburgh
1865. *Fairley, Thomas, F R S E, F C S 8 Newton-grove, Leeds.
1910. §Falconer, J. D. The Limes, Little Berkhamsted, Hertford.
1908 ‡Falconer, Robert A, M A 44 Merrion-square, Dublin
1896 §Falk, Herman John, M.A Thorshill, West Kirby, Cheshire.
1902 §Fallaize, E N, B A Vinchelez, Chase Court-gardens, Windmill-hill, Enfield
1907 *Fantham, H B, D Sc, B A 100 Mawson-road, Cambridge
1902 ‡Faren, William 11 Mount Charles, Belfast
1892. *Farmer, J Bretland, M.A, F R S, F L S (Pres K, 1907, Council, 1912-) South Park, Gerrards Cross
1886 ‡Farncombe, Joseph, J.P Saltwood, Spencer-road, Eastbourne.
1897 *Farnworth, Mrs Ernest Broadlands, Goldthorn Hill, Wolverhampton.
1904. ‡Farnworth, Miss Olive Broadlands, Goldthorn Hill, Wolverhampton.
1885. *Farquharson, Mrs R. F O Tillydrine, Kincardine O'Neil, N.B.
1905 ‡Farrar, Edward P O Box 1242, Johannesburg.
1903 §Faulkner, Joseph M 17 Great Ducie-street, Strangeways, Manchester
1890 *Fawcett, F B 1 Rockleaze-avenue, Sneyd Park, Bristol.
1906. §Fawcett, Henry Hargreave 20 Margaret-street, Cavendish-square, W.
1900 ‡Fawcett, J E, J P (Local Sec 1900) Low Royd, Apperley Bridge, Bradford
1902. *Fawsitt, C E, Ph D, Professor of Chemistry in the University of Sydney, New South Wales
1911 *Fay, Mrs A Q Chedworth, Rustat-road, Cambridge.
1909. *Fay, Charles Ryle, M A. Christ's College, Cambridge.
1906 *Fearnsides, Edwin G, M A, M B, B Sc London Hospital, E.
1901 *Fearnsides, W G, M A, F G S 49 Glisson-road, Cambridge
1910 *Fearnsides, Mrs 49 Glisson-road, Cambridge
1905 §Feilden, Colonel H W, C B, F R G S., F G S Burwash, Sussex.
1900 *Fennell, William John Deramore Drive, Belfast
1904 ‡Fenton, H J H, M A, F R S 19 Brookside, Cambridge.
1871 *Ferguson, John, M A, LL D, F R S E, F S A, F C S, Professor of Chemistry in the University of Glasgow.
1896 *Ferguson, Hon. John, C M G Naseby House, Newera Elliya, Ceylon.
1901. ‡Ferguson, R. W. Municipal Technical School, the Gamble Institute, St. Helens, Lancashire.
1863. *Fernie, John Box No. 2, Hutchinson, Kansas, U S.A
1910. *Ferranti, S. Z. de, M.Inst C E Grindleford, near Sheffield.
1905. *Ferrar, H. T, M A., F G.S. Geological Survey of Egypt, Giza, Egypt
1873. ‡Ferrier, Sir David, M.A, M D, LL.D., F.R.S, Professor of Neuro-Pathology in King's College, London. 34 Cavendish-square, W.
1909. ‡Fetherstonhaugh, Professor Edward P., B.Sc. 119 Betourney-street, Winnipeg, Canada.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.

Year of Election.

1897. ‡Field, George Wilton, Ph.D. Room 158, State House, Boston, Massachusetts, U.S.A.
1907. §Fields, Professor J. C. The University, Toronto, Canada.
1906. §FILON, L. N. G., D.Sc., F.R.S., Professor of Applied Mathematics in the University of London. Vega, Blenheim Park-road, Croydon.
1883. *Finch, Gerard B., M.A. Howes Close, Cambridge.
1905. ‡Fincham, G. H. Hopewell, Invami, Cape Colony.
1905. §Findlay, Alexander, M.A., Ph.D., D.Sc., Professor of Chemistry in University College, Aberystwyth.
1904. *Findlay, J. J., Ph.D., Professor of Education in the Victoria University, Manchester. Ruperra, Victoria Park, Manchester.
1912. §Finlayson, Daniel, F.L.S. Seed Testing Laboratory, Wood Green, N.
1902. ‡Finnegan, J., M.A., B.Sc. Kelvin House, Botanic-avenue, Belfast.
1902. ‡Fisher, J. R. Cranfield, Fortwilliam Park, Belfast.
1909. ‡Fisher, James, K.C. 216 Portage-avenue, Winnipeg, Canada.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlton Rectory, near Cambridge.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1887. *Fison, Alfred H., D.Sc. 47 Dartmouth-road, Willesden Green, N.W.
1871. *FISON, Sir FREDERICK W., Bart., M.A., F.C.S. Boarzell, Hurst Green, Sussex.
1885. *FITZGERALD, Professor MAURICE, B.A. (Local Sec. 1902.) Farnholme, Monkstown, Co. Dublin.
1894. ‡FITZMAURICE, Sir MAURICE, C.M.G., M.Inst.C.E. London County Council, Spring-gardens, S.W.
1888. *FITZPATRICK, Rev. THOMAS C., President of Queens' College, Cambridge.
1904. ‡Flather, J. H., M.A. Camden House, 90 Hills-road, Cambridge.
1904. ‡Fleming, James. 25 Kelvinside-terrace South, Glasgow.
1892. ‡Fletcher, George, F.G.S. 55 Pembroke-road, Dublin.
1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S. (Pres. C, 1894), Director of the Natural History Museum, Cromwell-road, S.W. 35 Woodville-gardens, Ealing, W.
1908. *Fletcher, W. H. B. Aldwick Manor, Bognor, Sussex.
1901. ‡Flett, J. S., M.A., D.Sc., F.R.S.E. 28 Jermyn-street, S.W.
1906. *Fleure, H. J., D.Sc., Professor of Zoology and Geology in University College, Aberystwyth.
1905. *Flint, Rev. W., D.D. Houses of Parliament, Cape Town.
1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.
1890. *FLUX, A. W., M.A. Board of Trade, Gwydyr House, Whitehall, S.W.
1877. ‡Foale, William. The Croft, Madeira Park, Tunbridge Wells.
1903. ‡Foord-Kelcey, W., Professor of Mathematics in the Royal Military Academy, Woolwich. The Shrubbery, Shooter's Hill, S.E.
1911. ‡Foran, Charles. 72 Elm-grove, Southsea.
1906. §Forbes, Charles Mansfeldt. 14 New-street, York.
1873. *FORBES, GEORGE, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 11 Little College-street, Westminster, S.W.
1883. ‡FORBES, HENRY O., LL.D., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.
1875. *FORDHAM, Sir GEORGE. Odsey, Ashwell, Baldock, Herts.
1909. ‡FORGET, The Hon. A. E. Regina, Saskatchewan, Canada.
1887. ‡FORREST, The Right Hon. Sir JOHN, G.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.

Year of Election

1902. *Forster, M. O , Ph D , D.Sc , F.R S. Imperial College of Scienc and Technology, S.W.
1883. ‡FORSYTH, A. R , M.A., D Sc., F R S (Pres. A, 1897, 1905; Council 1907-09.) Belgrave-mansions, Grosvenor-gardens, S.W.
1911. ‡Foster, F. G. Ivydale, London-road, Portsmouth.
1857. *FOSTER, GEORGE CAREY, B.A , LL D , D.Sc , F.R S. (GENERAL TREASURER, 1898–1904; Pres A, 1877 , Council, 1871–76 1877–82) Ladywalk, Rickmansworth.
1908. *Foster, John Arnold 11 Hills-place, Oxford Circus, W.
1901. §Foster, T. Gregory, Ph D., Provost of University College, London Chester-road, Northwood, Middlesex.
1911. ‡FOSTER, Sir T. SCOTT, J.P. Town Hall, Portsmouth.
1911 ‡Foster, Lady Scott. Braemar, St. Helen's-parade, Southsea.
1903. ‡Fourcade, H. G. P O , Storms River, Humansdorp, Cape Colony
1905. §Fowlds, Hiram 65 Devonshire-street, Keighley, Yorkshire.
1909. §Fowlds, Mrs. 65 Devonshire-street, Keighley, Yorkshire.
1912. §Fowler, A , F.R S , Assistant Professor of Physics in the Imperial College of Science and Technology, S W. 19 Rusthall-avenue Bedford Park, W
1906. §Fowler, Oliver H , M R C S Ashcroft House, Cirencester.
1883. *Fox, Charles The Pynes, Warlingham-on-the-Hill, Surrey.
1883 ‡Fox, Sir CHARLES DOUGLAS, M Inst.C E (Pres G, 1896.) Cross Keys House, 56 Moorgate-street, E.C.
1904. *Fox, Charles J. J , B Sc , Ph.D , Professor of Chemistry in the Presidency College of Science, Poona, India
1904 §Fox, F Douglas, M A , M Inst C E 19 The Square, Kensington, W.
1905 ‡Fox, Mrs. F Douglas. 19 The Square, Kensington, W.
1883 ‡Fox, Howard, F.G S Rosehill, Falmouth.
1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.
1900. *Fox, Thomas. Old Way House, Wellington, Somerset.
1909. *Fox, Wilson Lloyd. Carmino, Falmouth.
1908. §Foxley, Miss Barbara, M A. 5 Norton Way North, Letchworth.
1881. *FOXWELL, HERBERT S , M A , F S S (Council, 1894–97), Professor of Political Economy in University College, London. St. John's College, Cambridge
1907. §Fraine, Miss Ethel de, D.Sc , F L.S. 27 Bargery-road, Catford, S.E.
1887. *FRANKLAND, PERCY F , Ph D , B Sc., F.R S (Pres. B, 1901), Professor of Chemistry in the University of Birmingham.
1910. *FRANKLIN, GEORGE, Litt D Tapton Hall, Sheffield.
1911. ‡FRASER, Dr A MEARNS (Local Sec 1911.) Town Hall, Portsmouth.
1911. ‡Fraser, Mrs. A Mearns. Cheyne Lodge, St Ronan's-road, Portsmouth.
1895. ‡Fraser, Alexander 63 Church-street, Inverness
1885. ‡FRASER, ANGUS, M.A , M D , F.C.S (Local Sec. 1885) 232 Union-street, Aberdeen
1871. ‡FRASER, Sir THOMAS R , M.D , F R S., F R S E , Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1911. §Freeman, Oliver, B Sc. The Municipal College, Portsmouth.
1884. *FREMANTLE, The Hon Sir C. W , K C B. (Pres F, 1892 ; Council, 1897–1903) 4 Lower Sloane-street, S W.
1906. §French, Fleet-Surgeon A M. Langley, Beaufort-road, Kingston-on-Thames.
1909. ‡French, Mrs. Harriet A. Suite E, Gline's-block, Portage-avenue, Winnipeg, Canada.
1912. §French, Mrs. Harvey. 11 Foulis-terrace, Onslow-gardens, S.W.
1905. ‡French, Sir Somerset R., K.C.M.G. 100 Victoria-street, S.W.

Year of Election

1886. ‡**Freshfield, Douglas W.**, F R G S. (Pres. E, 1904) 1 Airlie-gardens, Campden Hill, W.
1887. *Fries, Harold H, Ph D. 92 Reade-street, New York, U S A.
1906. ‡Fritsch, Dr. F. E. 77 Chatsworth-road, Brondesbury, N.W
1892. *Frost, Edmund, M D. Chesterfield-road, Eastbourne
1912. §Frodsham, Miss Margaret, B.Sc The College School, 34 Cathedral-road, Cardiff.
1882. §Frost, Edward P, J P West Wratting Hall, Cambridgeshire.
1911. ‡Frost, M E P. H.M. Dockyard, Portsmouth.
1887. *Frost, Robert, B Sc 55 Kensington-court, W
1898. ‡**Fry, The Right Hon Sir Edward**, G C B, D C L, LL D, F R S, F S A Failand House, Failand, near Bristol
1875. *Fry, Joseph Storrs 16 Upper Belgrave-road, Clifton, Bristol.
1908 ‡Fry, M W J, M A 39 Trinity College, Dublin
1905 *Fry, William, J P, F R G S Wilton House, Merrion-road, Dublin.
1898. ‡Fryer, Alfred C, Ph D 13 Eaton-crescent, Clifton, Bristol.
1872 *Fuller, Rev A 7 Sydenham-hill, Sydenham, S E
1869. ‡**Fuller, G**, M Inst C E. (Local Sec. 1874) 71 Lexham-gardens, Kensington, W
1912. §Fulton, Angus R, B Sc University College, Dundee

1910. ‡Gadow, H F, Ph D, F R S Zoological Laboratory, Cambridge.
1863 *Gainsford, W D Skendleby Hall, Spilsby.
1906. §Gajjar, Professor T. K, M A, B Sc, Techno-Chemical Laboratory, near Girgaum Tram Terminus, Bombay
1885. *Gallaway, Alexander Dirgarve, Aberfeldy, N B
1875 ‡**Galloway, W** Cardiff
1887 *Galloway, W J The Cottage, Seymour-grove, Old Trafford, Manchester
1905 ‡Galpin, Ernest E Bank of Africa, Queenstown, Cape Colony
1913. §**Gamble, F W**, D Sc, F R S (Local Secretary, 1913), Professor of Zoology and Comparative Anatomy in the University of Birmingham 38 Frederick-road, Edgbaston, Birmingham
1888 ***Gamble, J Sykes**, C I E, M A, F R S, F L S Highfield, East Liss, Hants
1911. ‡Garbett, Rev C F, M A The Vicarage, Fratton-road, Portsmouth.
1899. *Garcke, E. Ditton House, near Maidenhead
1898 ‡Garde, Rev C L Skenfrith Vicarage, near Monmouth
1911. §Gardiner, C I, M A, F G S 6 Paragon-parade, Cheltenham
1912 §Gardiner, F A, F L S Inversnaid, West Heath-avenue, N W
1905. ‡Gardiner, J H. 59 Wroughton-road, Balham, S W.
1900 ‡**Gardiner, J. Stanley**, M A, F R S, Professor of Zoology and Comparative Anatomy in the University of Cambridge. Gonville and Caius College, Cambridge.
1887. ‡**Gardiner, Walter**, M A, D Sc, F R S St Awdreys, Hills-road, Cambridge
1882. *Gardner, H Dent, F R G S Fairmead, 46 The Goffs, Eastbourne
1912 §Gardner, Willoughby, M D Y Berlfa, Deganwy, North Wales.
1912. §Garfitt, G A Cartledge Hall, Holmesfield, near Sheffield.
1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.
1882. ‡Garnett, William, D C.L. London County Council, Victoria Embankment, W C.
1883. ‡**Garson, J. G.**, M.D. (Assist. Gen. Sec. 1902–04.) Moorcote, Eversley, Winchfield.

Year of Election

1903. ‡Garstang, A. H 82 Forest-road, Southport
1903. *Garstang, T James, M A Bedales School, Petersfield, Hampshire.
1894. *Garstang, Walter, M A, D Sc., F Z S, Professor of Zoology in the University of Leeds.
1874. *Garstin, John Ribton, M.A, LL B, M.R I A, F S A. Bragans-town, Castlebellingham, Ireland
1889. ‡Garwood, Professor E. J, M A, F.G S University College, Gower-street, W C
1905 ‡Gaskell, Miss C J The Uplands, Great Shelford, Cambridge
1905. ‡Gaskell, Miss M A The Uplands, Great Shelford, Cambridge
1896. *Gaskell, Walter Holbrook, M.A., M D., LL D, F R S (Pres I, 1896; Council, 1898–1901) The Uplands, Great Shelford, Cambridge.
1906. ‡Gaster, Leon. 32 Victoria-street, S.W.
1911. ‡Gates, W. 'Evening News' Office, Portsmouth.
1912. §Gavin, W., B A Hatfield Wick, Hatfield Peverel, Essex.
1905 *Gearon, Miss Susan 55 Buckleigh-road. Streatham Common, S W
1885 ‡Geddes, Professor Patrick 14 Ramsay-gardens, Edinburgh.
1867. ‡Geikie, Sir Archibald, K C B, LL D, D Sc, Pres R.S., F R S.E, F.G S (President, 1892, Pres C, 1867, 1871, 1899; Council, 1888–1891.) Shepherd's Down, Haslemere, Surrey.
1871. ‡Geikie, James, LL D, D C L, F R S, F.R.S E., F.G.S. (Pres. C, 1889; Pres E, 1892), Murchison Professor of Geology and Mineralogy in the University of Edinburgh. Kilmorie, Colinton-road, Edinburgh
1898 *Gemmill, James F, M A, M D 6 Strathmore-gardens, Hillhead, Glasgow
1882. *Genese, R W, M A, Professor of Mathematics in University College, Aberystwyth
1905 ‡Gentleman, Miss A A 9 Abercromby-place, Stirling
1912. *George, H Trevelyan, M A, M R C S, L R C P. 33 Ampthill-square, N W.
1902 *Gepp, Antony, M A, F L S British Museum (Natural History), Cromwell-road, S W
1899. *Gepp, Mrs A British Museum (Natural History), Cromwell-road, S W
1884. *Gerrans, Henry T, M.A 20 St John-street, Oxford.
1909. ‡Gibbons, W. M, M A. (Local Sec. 1910.) The University, Sheffield.
1905 ‡Gibbs, Miss Lilian S, F L S. 22 South-street, Thurloe-square, S W
1912. §Gibson, A H., D Sc, Professor of Engineering in University College, Dundee
1902 ‡Gibson, Andrew 14 Cliftonville-avenue, Belfast.
1901 ‡Gibson, Professor George A., M A 10 The University, Glasgow.
1912 §Gibson, G E, Ph D, B Sc 16 Woodhall-terrace, Juniper Green.
1876 *Gibson, George Alexander, M D, D Sc, LL.D, F.R S E. 3 Drums-heugh-gardens, Edinburgh.
1904. *Gibson, Mrs. Margaret D., LL.D Castle Brae, Chesterton-lane, Cambridge.
1912. *Gibson, Miss Mary H. Greystone Hall, Gainford, Darlington.
1896. ‡Gibson, R. J. Harvey, M.A, F.R.S.E, Professor of Botany in the University of Liverpool.
1889. *Gibson, T. G. Lesbury House, Lesbury, R S.O., Northumberland.
1893 ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W.
1898 *Gifford, J. William. Oaklands, Chard.

Year of Election

1883 §Gilbert, Lady. Park View, Englefield Green, Surrey.
1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
1895 ‡GILCHRIST, J. D F, M A, Ph D, B Sc, F L S Marine Biologist's Office, Department of Agriculture, Cape Town
1896. *GILCHRIST, PERCY C, F R S, M Inst C E Reform Club, Pall Mall, S.W.
1878. ‡Giles, Oliver. Brynteg, The Crescent, Bromsgrove
1871. *GILL, Sir DAVID, K C B, LL D, D Sc, F R S, Hon.F R.S E. (PRESIDENT, 1907) 34 De Vere-gardens, Kensington, W
1911. ‡Gill, Rev. H V, S.J. Milltown Park, Clonskea, Co Dublin.
1902 ‡Gill, James F 72 Strand-road, Bootle, Liverpool
1908. ‡Gill, T P. Department of Agriculture and Technical Instruction for Ireland, Dublin
1892 *Gilmour, Matthew A B, F Z S Saffronhall House, Windmill-road, Hamilton, N B
1907 ‡Gilmour, S C 25 Cumberland-road, Acton, W.
1908 ‡Gilmour, T L 1 St John's Wood Park, N W
1913 §Gilson, R Cary, M A King Edward's School Birmingham
1893 *Gimingham, Edward Croyland, Clapton Common, N
1904 ‡GINN, S R, D L (Local Sec 1904) Brookfield, Trumpington-road, Cambridge
1884 ‡Girdwood, G. P, M D 28 Beaver Hall-terrace, Montreal, Canada
1886 *Gisborne, Hartley, M Can S C E Yoxall, Ladysmith, Vancouver Island, Canada
1883. *Gladstone, Miss. 19 Chepstow-villas, Bayswater, W
1871. *GLAISHER, J W L, M A, D Sc, F R S, F R A S (Pres A, 1890; Council, 1878-86.) Trinity College, Cambridge
1880 *GLANTAWE, Right Hon Lord The Grange, Swansea
1881 *GLAZEBROOK, R T, C B, M A, D Sc, F R S (Pres A, 1893; Council 1890-94, 1905 11), Director of the National Physical Laboratory Bushy House, Teddington, Middlesex
1881 *Gleadow, Frederic 38 Ladbroke-grove, W
Glover, Thomas 124 Manchester-road, Southport
1878. *Godlee, J Lister. Wakes Colne Place, Essex
1880 ‡GODMAN, F DU CANE, D C L, F R S, F L S, F G S 45 Pont-street, S W
1879 ‡GODWIN-AUSTEN, Lieut -Colonel H H, F R S, F R G S, F Z S (Pres E, 1883) Nore, Godalming
1878 ‡GOFF, JAMES (Local Sec 1878) 29 Lower Leeson-street, Dublin
1908. *GOLD, ERNEST, M A. 4 Hurst Close, Brigwood-road, Hampstead Garden Suburb, N.W
1906. ‡GOLDIE, Right Hon. Sir GEORGE D T, K.C M G, D C L, F R S (Pres E, 1906, Council, 1906-07) 44 Rutland-gate, S W.
1910. §Golding, John, F I C Midland Agricultural and Dairy College, Kingston, near Derby
1898 ‡Goldney, F Bennett, F S A Goodnestone Park, Dover
1899. ‡GOMME, Sir G L, F S A 24 Dorset-square, N W
1890 *GONNER, E C. K, M A (Pres F, 1897), Prof ssor of Political Economy in the University of Liverpool
1909. ‡Goodair, Thomas. 303 Kennedy-street, Winnipeg, Canada.
1912. §Goodman, Sydney C M, B A 4 Paper-buildings, Temple, E C.
1907. §GOODRICH, E S, M A, F R S, F L S Merton College, Oxford
1884. *Goodridge, Richard E W P O Box 36, Coleraine, Minnesota, U S.A.
1884. ‡Goodwin, Professor W. L Queen's University, Kingston, Ontario, Canada.
1909. §Gordon, Rev. Charles W. 567 Broadway, Winnipeg, Canada.

Year of Election

1909. ‡Gordon, J. T. 147 Hargrave-street, Winnipeg, Canada.
1909. ‡Gordon, Mrs. J. T. 147 Hargrave-street, Winnipeg, Canada.
1911. *Gordon, J. W. 113 Broadhurst-gardens, Hampstead, N.W.
1871. *Gordon, Joseph Gordon, F.C S Queen Anne's-mansions, Westminster, S.W
1893. ‡Gordon, Mrs. M. M. Ogilvie, D Sc. 1 Rubislaw-terrace, Aberdeen.
1910. *Gordon, Vivian. Avonside Engine Works, Fishponds, Bristol.
1912. §Gordon, W. T Care of Rev J R Fraser, U.F. Manse, Kinneff, Bervie.
1901. ‡Gorst, Right Hon Sir John E, M A, K C, M P, F R S. (Pres. L, 1901) 21 Victoria-square, S.W
1875. *Gotch, Francis, M.A, D Sc., F R S (Pres I, 1906; Council, 1901–07), Professor of Physiology in the University of Oxford The Lawn, Banbury-road, Oxford.
1881. ‡Gough, Rev Thomas, B Sc King Edward's School, Retford
1901. ‡Gourlay, Robert. Glasgow
1876. ‡Gow, Robert. Cairndowan, Dowanhill-gardens, Glasgow.
1883 ‡Gow, Mrs. Cairndowan, Dowanhill-gardens, Glasgow.
1873. ‡Goyder, Dr D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1908. *Grabham, G. W, M A, F G S. P.O. Box 178, Khartoum, Sudan
1886 ‡Grabham, Michael C, M D Madeira
1909. ‡Grace, J. H., M A., F R S. Peterhouse, Cambridge.
1909. ‡Graham, Herbert W. 329 Kennedy-street, Winnipeg, Canada.
1902. *Graham, William, M D District Lunatic Asylum, Belfast.
1875. ‡Grahame, James. (Local Sec 1876) Care of Messrs. Grahame, Crums, & Connal, 34 West George-street, Glasgow.
1904. §Gramont, Comte Arnaud de, D Sc. 179 rue de l'Université, Paris
1896. ‡Grant, Sir James, K C M G. Ottawa, Canada
1908. *Grant, Professor W L Queen's University, Kingston, Ontario.
1890. ‡Gray, Andrew, M A, LL D, F R S, F R S E, Professor of Natural Philosophy in the University of Glasgow
1864. *Gray, Rev Canon Charles West Retford Rectory, Retford.
1881. ‡Gray, Edwin, LL B Minster-yard, York
1903. §Gray, Ernest, M A. 99 Grosvenor-road, S W.
1904. ‡Gray, Rev. H. B, D D (Pres. L, 1909) The College, Bradfield, Berkshire
1892. *Gray, James Hunter, M A, B Sc. 3 Crown Office-row, Temple, E C.
1887. ‡Gray, Joseph W., F G S 6 Richmond Park-crescent, Bournemouth.
1887. ‡Gray, M. H, F G S Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye Lessness Park, Abbey Wood, Kent.
1901. ‡Gray, R Whytlaw. University College, W.C.
1873 ‡Gray, William, M R I A. Glenburn Park, Belfast
*Gray, Colonel William. Farley Hall, near Reading.
1866 §Greaves, Charles Augustus, M B, LL B. 84 Friar-gate, Derby.
1910. ‡Greaves, R. H., B.Sc. 12 St. John's-crescent, Cardiff.
1904. *Green, Professor A G, M.Sc. The Old Gardens, Cardigan-road, Headingley, Leeds.
1904. §Green, F. W. 5 Wordsworth-grove, Cambridge.
1906 §Green, J. A., M.A., Professor of Education in the University of Sheffield.
1888 §Green, J. Reynolds, M.A, D.Sc, F.R.S, F.L.S. (Pres. K, 1902.) Downing College, Cambridge.

Year of Election

1903. ‡*Green, W. J. 76 Alexandra-road, N.W.*
1908. ‡Green, Rev. William Spotswood, C B , F R G S 5 Cowper-villas, Cowper-road, Dublin
1909. ‡Greenfield, Joseph. P.O Box 2935, Winnipeg, Canada.
1882. ‡GREENHILL, Sir A G , M A , F R S. 1 Staple Inn, W C.
1905. ‡Greenhill, William. 6A George-street, Edinburgh.
1898. *GREENLY, EDWARD, F G S Achnashean, near Bangor, North Wales
1875. ‡Greenwood, Dr. Frederick. Brampton, Chesterfield.
1906. ‡Greenwood, Hamar. National Liberal Club, Whitehall-place, S W.
1894. *GREGORY, J. WALTER, D Sc , F R S , F G S (Pres C, 1907), Professor of Geology in the University of Glasgow
1896. *GREGORY, Professor R A , F R A S Dell Quay House, near Chichester
1904. *Gregory, R P., M A 156 Chesterton-road, Cambridge.
1881 ‡Gregson, William, F G S 106 Victoria-road, Darlington.
1836. Griffin, S F Albion Tin Works, York-road, N
1894. *Griffith, C L T , Assoc M Inst.C E , Professor of Civil Engineering in the College of Engineering, Madras
1908. §Griffith, Sir John P , M Inst C E Rathmines Castle, Rathmines, Dublin
1884. ‡GRIFFITHS, E H , M A , D Sc , F.R S (Pres A, 1906, Council, 1911–), Principal of University College, Cardiff.
1884 ‡Griffiths, Mrs. University College, Cardiff
1903. ‡Griffiths, Thomas, J P 101 Manchester-road, Southport.
1888. *Grimshaw, James Walter, M Inst C E St Stephen's Club, Westminster, S W
1911. ‡Grogan, Ewart S Camp Hill, near Newcastle, Staffs
1894 ‡GROOM, Professor P , M A , F L S North Park, Gerrard's Cross, Bucks.
1894. ‡Groom, T. T , M A , D Sc , F G S , Professor of Geology in the University of Birmingham.
1909. *Grossman, Edward L , M D. Steilacoom, Washington, U S A.
1896. ‡Grossmann, Dr Karl 70 Rodney-street, Liverpool.
1904. ‡Grosvenor, G H. New College, Oxford
1869. ‡GRUBB, Sir HOWARD, F R S , F R A S. Aberfoyle, Rathgar, Dublin
1897. ‡Grunbaum, A. S , M A , M D. School of Medicine, Leeds.
1910. §Grundy, James Ruislip, Teignmouth-road, Cricklewood, N W.
1887. ‡GUILLEMARD, F. H H , M A , M.D The Mill House, Trumpington, Cambridge.
1905. *Gunn, Donald. Royal Societies Club, St James's-street, S W
1909. ‡Gunne, J. R., M D. Kenora, Ontario, Canada.
1909. ‡Gunne, W. J , M D Kenora, Ontario, Canada.
1866 ‡GUNTHER, ALBERT C. L. G , M A , M D , Ph D , F.R S , F.L S , F.Z S. (Pres D, 1880) 22 Lichfield-road, Kew, Surrey.
1894. ‡Günther, R. T. Magdalen College, Oxford
1880. §Guppy, John J. Ivy-place, High-street, Swansea
1904. §Gurney, Sir Eustace Sprowston Hall, Norwich.
1902 *Gurney, Robert. Ingham Old Hall, Stalham, Norfolk
1904. ‡Guttmann, Professor Leo F., Ph.D. Queen's University, Kingston, Canada.
1895 ‡Gwynne-Vaughan, D T , F L S , Professor of Botany in Queen's University, Belfast
1906. *GWYNNE-VAUGHAN, Mrs HELEN C I , D Sc , F L S Department of Botany, Birkbeck College, London, W C. 27 Lincoln's Inn-fields, W.C.

Year of Election

1905. ‡Hacker, Rev. W. J. Idutywa, Transkei, South Africa.
1908. *Hackett, Felix E. Royal College of Science, Dublin.
1881 *HADDON, ALFRED CORT, M A , D Sc , F.R.S., F Z S (Pres. H, 1902, 1905 , Council, 1902–08, 1910– .) 3 Cranmer-road, Cambridge
1911. *Haddon, Miss Kathleen Inisfail, Hills-road, Cambridge.
1888. *Hadfield, Sir R A , F R S , M Inst C E. 22 Carlton House-terrace, S W
1905 ‡Hahn, Professor P H , M A , Ph D York House, Gardens, Cape Town.
1911. §Haigh, B P., B Sc. James Watt Engineering Laboratory, The University, Glasgow.
1906. ‡Hake, George W. Oxford, Ohio, U S A
1894. ‡HALDANE, JOHN SCOTT, M A , M D , F R S (Pres I, 1908), Reader in Physiology in the University of Oxford Cherwell, Oxford
1909. §Hale, W. H , Ph D 40 First-place, Brooklyn, New York, U S.A.
1911. §Halket, Miss A C Waverley House, 135 East India-road, E.
1899 ‡HALL, A D , M A , F R S (Council, 1908–) Development Commission, Queen Anne's-chambers, S W
1909. §Hall, Archibald A , M Sc , Ph D. Armstrong College, Newcastle-on-Tyne.
1903 ‡HALL, E MARSHALL, K C 75 Cambridge-terrace, W.
1879 *Hall, Ebenezer Abbeydale Park, near Sheffield
1883. *Hall, Miss Emily 63 Belmont street, Southport.
1854 *HALL, HUGH FERGIE, F G S. Cissbury Court, West Worthing, Sussex.
1899 ‡Hall, John, M D National Bank of Scotland, 37 Nicholas-lane, E C
1884. §Hall, Thomas Proctor, M.D. 1301 Davie-street, Vancouver, B.C , Canada
1908 *Hall, Wilfred, Assoc M Inst C E 9 Prior's-terrace, Tynemouth, Northumberland
1891. *Hallett, George. Cranford, Victoria-square, Penarth.
1873 *HALLETT, T G P , M A Claverton Lodge, Bath
1888. §HALLIBURTON, W D , M D , LL D , F R S (Pres I, 1902 ; Council, 1897–1903, 1911–), Professor of Physiology in King's College, London Church Cottage, 17 Marylebone-road, N.W
1905. ‡Halliburton, Mrs Church Cottage, 17 Marylebone-road, N W.
1904. *Hallidie, A H S Avondale, Chesterfield-road, Eastbourne
1908 ‡Hallitt, Mrs Steeple Grange, Wirksworth
1908 *Hamel, Egbert Alexander de Middleton Hall, Tamworth
1883 *Hamel, Egbert D de Middleton Hall, Tamworth
1904. *Hamel de Manin, Anna Countess de 35 Circus-road, N.W.
1906 ‡Hamill, John Molyneux, M A , M B 14 South-parade, Chiswick.
1906 ‡Hamilton, Charles I 88 Twyford-avenue, Acton
1909. ‡Hamilton, F. C Bank of Hamilton-chambers, Winnipeg, Canada.
1902 ‡HAMILTON, Rev T , D D Queen's College, Belfast
1909. ‡Hamilton, T Glen, M D 264 Renton-avenue, Winnipeg, Canada.
1881. *HAMMOND, ROBERT, M Inst C E 64 Victoria-street, Westminster, S.W
1899 *Hanbury, Daniel Lenqua da Cà, Alassio, Italy.
1878. ‡Hance, E. M Care of J Hope Smith, Esq , 3 Leman-street, E C.
1909. ‡Hancock, C. B. Manitoba Government Telephones, Winnipeg, Canada
1905. *Hancock, Strangman Kennel Holt, Cranbrook, Kent.
1912. §Hankin, G. T. 150 Whitehall-court, S.W.
1911. ‡Hann, H. F. 139 Victoria-road North, Southsea.

Year of Election

1906. §Hanson, David Salterlee, Halifax, Yorkshire
1904. §Hanson, E. K 2A The Parade, High-street, Watford; and Woodthorpe, Royston Park-road, Hatch End, Middlesex
1859 *HARCOURT, A. G VERNON, M A, D C L, LL D, D Sc, F R S, V P C S (GEN SEC 1883-97; Pres B, 1875; Council, 1881-83) St Clare, Ryde, Isle of Wight
1909. §Harcourt, George. Department of Agriculture, Edmonton, Alberta, Canada.
1886 *Hardcastle, Colonel Basil W, F S S 12 Gainsborough-gardens, Hampstead, N W
1902 *HARDCASTLE, MISS FRANCES 3 Osborne-terrace, Newcastle-on-Tyne
1903 *Hardcastle, J Alfred The Dial House, Crowthorne, Berkshire
1892 *HARDEN, ARTHUR, Ph D, D Sc, F R S Lister Institute of Preventive Medicine Chelsea-gardens, Grosvenor-road, S W.
1905 ‡*Hardie, Miss Mabel, M B High-lane, via Stockport*
1877 ‡Harding, Stephen Bower Ashton, Clifton, Bristol
1894 ‡Hardman, S C 120 Lord-street, Southport
1909. §HARDY, W. B, M A, F R S Gonville and Caius College, Cambridge.
1881 ‡Hargrove, William Wallace St Mary's, Bootham, York
1890 *HARKER, ALFRED, M A, F R S, F G S (Pres C, 1911) St John's College, Cambridge
1896 ‡Harker, John Allen, D Sc, F R S National Physical Laboratory, Bushy House, Teddington
1875 *Harland, Rev Albert Augustus, M A, F G S, F L S, F S A The Vicarage, Harefield, Middlesex
1877 *Harland, Henry Seaton 8 Arundel-terrace, Brighton
1883. *Harley, Miss Clara Rastrick, Cricketfield-road, Torquay
1899. ‡Harman, Dr N Bishop, F R C S 108 Harley street, W.
1868 *HARMER, F W, F G S Oakland House, Cringleford, Norwich
1881. *HARMER, SIDNEY F, M A, Sc D, F R S. (Pres D, 1908) Keeper of the Department of Zoology, British Museum (Natural History), Cromwell-road, S W.
1912 *Harper, Alan G, B A Magdalen College, Oxford
1906 ‡Harper, J B 16 St George's-place, York
1842. *Harris, G. W Millicent, South Australia
1909. ‡Harris, J. W. Civic Offices, Winnipeg
1903. ‡Harris, Robert, M B Queen's-road, Southport
1904 *Harrison, Frank L, B A, B Sc Brook-street, Soham, Cambridgeshire.
1904. ‡Harrison, H Spencer The Horniman Museum, Forest-hill, S E
1892. ‡HARRISON, JOHN (Local Sec 1892) Rockville, Napier-road, Edinburgh.
1892. ‡Harrison, Rev S N Ramsey, Isle of Man
1901. *Harrison, W E 17 Soho-road, Handsworth, Staffordshire
1911. ‡Harrison-Smith, F, C B H M Dockyard, Portsmouth.
1885. ‡HART, Colonel C J. (Local Sec 1886) Highfield Gate, Edgbaston, Birmingham
1909. ‡Hart, John A. 120 Emily-street, Winnipeg, Canada.
1876. *Hart, Thomas Brooklands, Blackburn
1903 *Hart, Thomas Clifford Brooklands, Blackburn
1907. §Hart, W. E. Kilderry, near Londonderry.
1911. §Hart-Synnot, Ronald V.O. University College, Reading.
1893. *HARTLAND, E. SIDNEY, F S A (Pres H, 1906; Council, 1906-) Highgarth, Gloucester
1905. ‡Hartland, Miss Highgarth, Gloucester

Year of Election

1871. *HARTLEY, Sir WALTER NOEL, D Sc., F.R S , F.R.S.E., F.C.S. (Pres. B, 1903) Care of Mrs. Thompson, Forge House, Newtown Park, Blackrock, Co. Dublin.
1886. *HARTOG, Professor M M , D Sc. University College, Cork.
1887. ‡HARTOG, P. J., B Sc. University of London, South Kensington, S.W.
1885. §Harvie-Brown, J. A , LL.D. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1893. §Haslam, Lewis. 8 Wilton-crescent, S W.
1911. *Hassé, H. R. The University, Manchester.
1903. *Hastie, Miss J. A. Care of Messrs Street & Co , 30 Cornhill, E.C.
1904. ‡HASTINGS, G 15 Oak-lane, Bradford, Yorkshire
1875. *HASTINGS, G. W. (Pres. F, 1880) Chapel House, Chipping Norton.
1903. ‡Hastings, W. G W 2 Halsey-street, Cadogan-gardens, S W.
1889 ‡HATCH, F H , Ph.D., F.G S. Southacre, Trumpington-road, Cambridge.
1903. ‡Hathaway, Herbert G 45 High-street, Bridgnorth, Salop
1904 *Haughton, W T H The Highlands, Great Barford, St Neots.
1908. §Havelock, T H , M A , D Sc Rockliffe, Gosforth, Newcastle-on-Tyne
1904. ‡Havilland, Hugh de Eton College, Windsor
1887. *Hawkins, William Earlston House, Broughton Park, Manchester.
1872 *Hawkshaw, Henry Paul. 58 Jermyn-street, St James's, S W.
1864. *HAWKSHAW, JOHN CLARKE, M A , M Inst C E , F G S (Council, 1881–87) 22 Down-street, W
1897. §HAWKSLEY, CHARLES, M Inst.C E , F G S (Pres G, 1903 ; Council, 1902–09.) Caxton House (West Block), Westminster, S.W.
1887. *Haworth, Jesse Woodside, Bowdon, Cheshire
1885. *HAYCRAFT, JOHN BERRY, M D , B Sc , F R S E , Professor of Physiology in University College, Cardiff.
1900. §Hayden, H H , B A , F G S Geological Survey, Calcutta, India.
1903. *Haydock, Arthur 114 Revidge-road, Blackburn
1903. ‡Hayward, Joseph William, M.Sc. Keldon, St. Marychurch, Torquay.
1896. *Haywood, Colonel A G Rearsby, Merrilocks-road, Blundellsands
1883. ‡Heape, Joseph R Glebe House, Rochdale
1882 *Heape, Walter, M.A , F R S Greyfriars, Southwold, Suffolk
1909. §Heard, Mrs. Sophie, M B , Ch B Carisbrooke, Fareham, Hants
1908. §Heath, J St George, B A Woodbrooke Settlement, Selly Oak, near Birmingham
1902 ‡Heath, J W Royal Institution, Albemarle-street, W.
1909. ‡Heathcote, F. C. C. Broadway, Winnipeg, Canada.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport
1913. §HEATON, HOWARD (LOCAL SECRETARY, 1913) Wayside, Lode-lane, Solihull, Birmingham.
1892. *HEATON, WILLIAM H , M A (Local Sec. 1893), Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West, I S.O. 12 Tring-avenue, Ealing, W.
1888. *HEAWOOD, EDWARD, M.A. Briarfield, Church-hill, Merstham, Surrey.
1888. *Heawood, Percy J , Professor of Mathematics in Durham University. 41 Old Elvet, Durham
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. 10 Cranley-place, South Kensington, S W.
1912. §Hedley, Charles. Australian Museum, Sydney.

Year of Election.

1881. *HELE-SHAW, H. S., D.Sc., LL D, F.R.S, M.Inst.C.E. 64 Victoria-street, S W
1901. *HELLER, W. M., B.Sc. 59 Upper Mount-street, Dublin.
1911. ‡Hellyer, Francis E. Farlington House, Havant, Hants.
1911. §Hellyer, George E Farlington House, Havant, Hants.
1887. ‡Hembry, Frederick William, F R M S City-chambers, 2 St Nicholas-street, Bristol.
1899. ‡Hemsalech, G A, D Sc The Owens College, Manchester
1905. *Henderson, Andrew 17 Belhaven-terrace, Glasgow
1905. *Henderson, Miss Catharine 17 Belhaven-terrace, Glasgow
1891. *HENDERSON, G G, D Sc, M A, F I C, Professor of Chemistry in the Glasgow and West of Scotland Technical College, Glasgow
1905. §Henderson, Mrs 7 Marlborough-drive, Kelvinside, Glasgow.
1907. §Henderson, H F. Felday, Morland-avenue, Leicester
1906 ‡Henderson, J. B, D Sc, Professor of Applied Mechanics in the Royal Naval College, Greenwich, S E
1909. ‡Henderson, Veylien E. Medical Building, The University, Toronto, Canada.
1909. ‡Henderson, W. G. Louise Bridge, Winnipeg, Canada.
1880. *Henderson, Admiral W H, R N 12 Vicarage-gardens, Campden Hill, W
1911. §Henderson, William Dawson The University, Bristol
1904. *Hendrick, James Marischal College, Aberdeen
1910. ‡Heney, T W. Sydney, New South Wales
1910. *HENRICI, Captain E O, R E, A Inst C E Ordnance Survey Office, Southampton
1873. *HENRICI, OLAUS M F. E, Ph D F R S (Pres A, 1883; Council, 1883-89) 34 Clarendon-road, Notting Hill, W
1910. ‡Henry, Hubert, M D. 304 Glossop-road, Sheffield
1906 ‡Henry, Dr T A Imperial Institute, S W
1909. *Henshall, Robert. Sunnyside, Latchford, Warrington.
1892 ‡HEPBURN, DAVID, M D, F R S E, Professor of Anatomy in University College, Cardiff
1904. ‡Hepworth, Commander M W C, C B, R N R Meteorological Office, South Kensington, S W
1892. *HERBERTSON, A J, M A, Ph D (Pres E, 1910), Professor of Geography in the University of Oxford 9 Fyfield-road, Oxford
1909. ‡Herbinson, William. 376 Ellice-avenue, Winnipeg, Canada.
1902 ‡Herdman, G W, B Sc, Assoc M Inst C E Irrigation and Water Supply Department, Pretoria
1912. *Herdman, George Andrew Croxteth Lodge, Sefton Park, Liverpool.
1887. *HERDMAN, WILLIAM A, D Sc, F R S, F R S.E, F L S (GENERAL SECRETARY, 1903- , Pres D, 1895; Council, 1894-1900, Local Sec 1896), Professor of Natural History in the University of Liverpool Croxteth Lodge, Sefton Park, Liverpool
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool
1909. ‡Herdt, Professor L. A. McGill University, Montreal, Canada.
1875. ‡HEREFORD, The Right Rev. JOHN PERCIVAL, D D, LL D, Lord Bishop of. (Pres L, 1904) The Palace, Hereford
1912. §Heron, David, D Sc. Galton Eugenics Laboratory, University College, W C
1912. §Heron-Allen, Edward, F.L.S, F G S 33 Hamilton-terrace, N W.
1908. *Herring, Dr. Percy T. The University, St. Andrews, N.B.
1874. §HERSCHEL, Colonel JOHN, R E., F.R S, F.R.A.S. Observatory House, Slough, Bucks.

Year of Election

1900 *Herschel, Rev. J. C. W. Firoroft, Wellington College Station, Berkshire.
1905. ‡Hervey, Miss Mary F. S. 22 Morpeth-mansions, S.W.
1903 *HESKETH, CHARLES H. FLEETWOOD, M A. Stocken Hall, Stretton, Oakham.
1895. §Hesketh, James 5 Scarisbrick Avenue, Southport.
1894. ‡HEWETSON, G H. (Local Sec 1896) 39 Henley-road, Ipswich.
1894. ‡Hewins, W. A S., M.A., F.S.S. 15 Chartfield-avenue, Putney Hill, S.W.
1908 ‡Hewitt, Dr. C Gordon Central Experimental Farm, Ottawa.
1896. §Hewitt, David Basil, M D Oakleigh, Northwich, Cheshire.
1903 ‡Hewitt, E G W 87 Princess-road, Moss Side, Manchester.
1909 §Hewitt, Sir Frederic, M V O, M D 14 Queen Anne-street, W
1903 ‡Hewitt, John Theodore, M A, D Sc, Ph D, F.R S. Clifford House, Staines-road, Bedfont, Middlesex
1909. ‡Hewitt, W., B.Sc. 16 Clarence-road, Birkenhead
1882 *HEYCOCK, CHARLES T, M A, F R S 3 St Peter's-terrace, Cambridge.
1883. ‡Heyes, Rev. John Frederick, M A, F R G S. St Barnabas Vicarage, Bolton
1866. *Heymann, Albert West Bridgford, Nottinghamshire
1901 *Heys, Z John Stonehouse, Barrhead, N B
1912 §Heywood, H B, D Sc Bedford College, Baker-street, W.
1886 ‡HEYWOOD, HENRY, J P Witla Court, near Cardiff
1912 §Hickling, George The University, Manchester
1877. §HICKS, W M, M A, D Sc, F R S (Vice-Pres. 1910; Pres A, 1895), Professor of Physics in the University of Sheffield Leamhurst, Ivy Park-road, Sheffield
1886 ‡Hicks, Mrs W M Leamhurst, Ivy Park-road, Sheffield
1887 *HICKSON, SYDNEY J, M A, D Sc, F R S (Pres D, 1903), Professor of Zoology in Victoria University, Manchester.
1864. *HIERN, W P, M A, F R S The Castle, Barnstaple
1891. ‡HIGGS, HENRY, C B, LL.B, F S S (Pres F, 1899; Council, 1904–06) H M Treasury, Whitehall, S W
1909. ‡Higman, Ormond. Electrical Standards Laboratory, Ottawa.
1907 ‡HILEY, E V (Local Sec 1907) Town Hall, Birmingham.
1911. *Hiley, Wilfrid E Ebbor, Wells, Somerset.
1885. *HILL, ALEXANDER, M.A, M D Hartley University College, Southampton
1903 *HILL, ARTHUR W, M.A., F.L.S. Royal Gardens, Kew
1906. §Hill, Charles A, M.A., M B 13 Rodney-street, Liverpool
1881. *HILL, Rev EDWIN, M A The Rectory, Cockfield, Bury St Edmunds
1908 *Hill, James P, D.Sc., Professor of Zoology in University College, Gower-street, W C
1911 §HILL, LEONARD, M B, F.R S (Pres. I, 1912) Osborne House, Loughton, Essex
1912 §Hill, M. D Angelo's, Eton College, Windsor.
1886. ‡HILL, M. J. M., M A, D Sc., F.R S, Professor of Pure Mathematics in University College, W.C
1898. *Hill, Thomas Sidney. Langford House, Langford, near Bristol.
1888. ‡Hill, William, F G.S. The Maples, Hitchin, Herts.
1907. *HILLS, Major E. H, C M.G, R E., F.R.S., F.R.G.S. (Pres. E, 1908) 32 Prince's-gardens, S W.
1911. *Hills, William Frederick Waller. 32 Prince's-gardens, S.W.
1903. *Hilton, Harold. 73 Platt's-lane, Hampstead, N.W.
1903. *HIND, WHEELTON, M.D., F G S. Roxeth House, Stoke-on-Trent.
1870. ‡HINDE, G. J., Ph.D, F.R.S., F.G.S. Ivythorn, Avondale-road, South Croydon, Surrey.

Year of Election

1910. §Hindle, Edward, B A, Ph.D, F L S. Quick Laboratories, Cambridge.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington
1888. *Hindmarsh, W. T., F.L S Alnbank, Alnwick.
1898. §Hinds, Henry. 57 Queen-street, Ramsgate
1900 ‡Hinks, Arthur R, M A The Observatory, Cambridge
1903. *Hinmers, Edward. Glentwood, South Downs-drive, Hale, Cheshire.
1911. ‡*Hitchcock, Miss A M, M A* 40 *St Andrew's-road, Southsea*
1899. ‡Hobday, Henry Hazelwood, Crabble Hill, Dover
1887. *HOBSON, BERNARD, M Sc, F G S Thornton, Hallam Gate-road, Sheffield.
1904. ‡HOBSON, ERNEST WILLIAM, Sc D, F R S (Pres A, 1910), Sadlerian Professor of Pure Mathematics in the University of Cambridge. The Gables, Mount Pleasant, Cambridge.
1907. ‡Hobson, Mrs Mary. 6 Hopefield-avenue, Belfast
1877. ‡Hodge, Rev John Mackey, M A 38 Tavistock-place, Plymouth
1887. *Hodgkinson, Alexander, M B, B Sc, Lecturer on Laryngology in the Victoria University, Manchester 18 St John-street, Manchester
1880. ‡Hodgkinson, W. R Eaton, Ph D, F R S E, F G S, Professor of Chemistry and Physics in the Royal Artillery College, Woolwich 18 Glenluce-road, Blackheath, S E
1905. ‡Hodgson, Ven Archdeacon R The Rectory, Wolverhampton
1912. §Hodgson, Benjamin The University, Bristol
1909. ‡Hodgson, R. T., M A. Collegiate Institute, Brandon, Manitoba, Canada.
1898 ‡Hodgson, T V Municipal Museum and Art Gallery, Plymouth
1904. §Hodson, F, Ph D Bablake School, Coventry.
1904. ‡HOGARTH, D G, M A (Pres H, 1907; Council, 1907-10) 20 St. Giles's, Oxford.
1908. ‡Hogg, Right Hon Jonathan Stratford, Rathgar, Co Dublin
1911. ‡Holbrook, Colonel A R Warleigh, Grove-road South, Southsea
1907. ‡Holden, Colonel H C. L, R A, F.R S Gifford House, Blackheath, S E
1883. ‡Holden, John J 73 Albert-road, Southport
1887 *Holder, Henry William, M A. Beechmount, Arnside.
1900 ‡HOLDICH, Colonel Sir THOMAS H, R E, K.C B, K C I E, F R G S. (Pres E, 1902) 41 Courtfield-road, S W
1887. *Holdsworth, C J, J.P. Fernhill, Alderley Edge, Cheshire
1904. §Holland, Charles E 9 Downing-place, Cambridge
1903 §Holland, J L, B A 3 Primrose-hill, Northampton
1896. ‡Holland, Mrs. Lowfields House, Hooton, Cheshire
1898. ‡HOLLAND, Sir THOMAS H, K C I.E., F R S, F G S, Professor of Geology in the Victoria University, Manchester.
1889. ‡Hollander, Bernard, M D 35A Welbeck-street, W
1906. *Hollingworth, Miss Leithen, Newnham-road, Bedford
1883. *Holmes, Mrs Basil 23 Corfton-road, Ealing, Middlesex, W.
1866 *Holmes, Charles. Makeney, Compton-road, Winchmore Hill, N
1882. *HOLMES, THOMAS VINCENT, F G S 28 Croom's-hill, Greenwich, S E.
1912. §Holmes-Smith, Edward, B Sc. Royal Botanic Gardens, Edinburgh
1903. *HOLT, ALFRED, M.A, D Sc Dowsefield, Allerton, Liverpool
1875. *Hood, John. Chesterton, Cirencester.
1904. §Hooke, Rev. D. Burford, D.D. Somerset Lodge, Barnet.
1892. ‡*HOOKER, REGINALD H., M.A.* 3 *Clement's Inn, W C.*
1908. *Hooper, Frank Henry Clare College, Cambridge.
1865. *Hooper, John P. Deepdene, Streatham Common, S.W.

Year of Election

1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
1904. ‡Hopewell-Smith, A, M.R.C.S. 37 Park-street, Grosvenor-square, S.W.
1905. *Hopkins, Charles Hadley. Junior Constitutional Club, 101 Piccadilly, W.
1913. §HOPKINS, F. G., M.A., D.Sc., M.B., F.R.S. Trinity College, and Saxmeadham, Grange-road, Cambridge.
1901. *HOPKINSON, BERTRAM, M.A., F.R.S., F.R.S.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. Adams-road, Cambridge.
1884. *HOPKINSON, CHARLES (Local Sec. 1887.) The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Ferns, Alderley Edge, Cheshire.
1871. *HOPKINSON, JOHN, Assoc.Inst.C.E., F.L.S., F.G.S., F.R.Met.Soc. Weetwood, Watford.
1905. ‡Hopkinson, Mrs. John. Holmwood, Wimbledon Common, S.W.
1898. *Hornby, R., M.A. Haileybury College, Hertford.
1910. ‡Horne, Arthur S. 48 Highbury, Newcastle-on-Tyne.
1885. ‡HORNE, JOHN, LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1901.) 12 Keith-crescent, Blackhall, Midlothian.
1903. ‡Horne, William, F.G.S. Leyburn, Yorkshire.
1902. ‡Horner, John. Chelsea, Antrim-road, Belfast.
1905. *Horsburgh, E. M., M.A., B.Sc., Lecturer in Technical Mathematics in the University of Edinburgh.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *HORSLEY, Sir VICTOR A. H., LL.D., B.Sc., F.R.S., F.R.C.S. (Council, 1893–98.) 25 Cavendish-square, W.
1908. ‡Horton, F. St. John's College, Cambridge.
1884. *Hotblack, G. S. Brundall, Norwich.
1899. ‡Hotblack, J. T., F.G.S. 45 Newmarket-road, Norwich.
1906. *Hough, Miss Ethel M. Codsall Wood, near Wolverhampton.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S., M.A., F.R.S., F.R.A.S., His Majesty's Astronomer at the Cape of Good Hope. Royal Observatory, Cape Town.
1905. §Houghting, A. G. L. Glenelg, Musgrave-road, Durban, Natal.
1908. ‡Houston, David, F.L.S. Royal College of Science, Dublin.
1893. ‡Howard, F. T., M.A., F.G.S. West Mount, Waverton, near Chester.
1904. *Howard, Mrs. G. L. C. Agricultural Research Institute, Pusa, Bengal, India.
1887. *Howard, S. S. 54 Albemarle-road, Beckenham, Kent.
1901. §Howarth, E., F.R.A.S. Public Museum, Weston Park, Sheffield.
1903. *Howarth, James H., F.G.S. Holly Bank, Halifax.
1907. ‡HOWARTH, O. J. R., M.A. (ASSISTANT SECRETARY.) 24 Lansdowne-crescent, W.
1911. *Howe, Professor G. W. O., M.Sc. 14 Bernard-gardens, Wimbledon, S.W.
1905. ‡Howick, Dr. W. P.O. Box 503, Johannesburg.
1863. ‡HOWORTH, Sir H. H., K.C.I.E., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.
1887. §HOYLE, WILLIAM E., M.A., D.Sc. (Pres. D, 1907.) National Museum of Wales, City Hall, Cardiff.
1903. ‡Hubner, Julius. Ash Villa, Cheadle Hulme, Cheshire.
1898. ‡Hudson, Mrs. Sunny Bank, Egerton, Huddersfield.
1867. *HUDSON, Professor WILLIAM H. H., M.A., LL.M. 34 Birdhurst-road, Croydon.

Year of Election

1871. *Hughes, George Pringle, J.P., F.R.G.S. Middleton Hall, Wooler, Northumberland

1868. ‡HUGHES, T. M'K., M.A., F.R.S., F.G.S. (Council, 1879–86), Woodwardian Professor of Geology in the University of Cambridge. Ravensworth, Brooklands-avenue, Cambridge

1867. ‡HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S. (Pres. C, 1874.) 14 Stanley-gardens, Notting Hill, W.

1903. ‡Hulton, Campbell G. Palace Hotel, Southport

1905. §Hume, D. G. W. 55 Gladstone-street, Dundee, Natal.

1911. *Hume, Dr. W. F. Helwan, Egypt.

1904. *Humphreys, Alexander C., Sc.D., LL.D., President of the Stevens Institute of Technology, Hoboken, New Jersey, U.S.A.

1913. §HUMPHREYS, JOHN. (LOCAL SECRETARY, 1913.) 26 Clarendon-road, Edgbaston, Birmingham

1907. §Humphries, Albert E. Coxe's Lock Mills, Weybridge

1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay

1891. *Hunt, Cecil Arthur, Southwood, Torquay

1881. ‡Hunter, F. W. 16 Old Elvet, Durham.

1889. ‡Hunter, Mrs. F. W. 16 Old Elvet, Durham

1909. ‡Hunter, W. J. H. 31 Lynedoch-street, Glasgow.

1901. *Hunter, William. Evirallan, Stirling

1903. ‡Hurst, Charles C., F.L.S. Burbage, Hinckley

1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland

1894. *HUTCHINSON, A., M.A., Ph.D. (Local Sec. 1904.) Pembroke College, Cambridge

1912. §Hutchinson, Dr. H. B. Rothamsted Experimental Station, Harpenden, Herts

1903. §Hutchinson, Rev. H. N. 17 St. John's Wood Park, Finchley-road, N.W.

1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.

1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.

1901. *Hutton, R. S., D.Sc. West-street, Sheffield

1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire

1900. *Hyndman, H. H. Francis. 5 Warwick-road, Earl's Court, S.W.

1908. ‡Idle, George. 43 Dawson-street, Dublin

1883. ‡Idris, T. H. W. 110 Pratt-street, Camden Town, N.W.

1884. *Iles, George. 5 Brunswick-street, Montreal, Canada

1906. ‡Iliffe, J. W. Oak Tower, Upperthorpe, Sheffield

1885. ‡im Thurn, Sir Everard F., C.B., K.C.M.G. 1 East India-avenue, Leadenhall-street, E.C.

1907. §Ingham, Charles B. Moira House, Eastbourne

1893. ‡Ingle, Herbert. Department of Agriculture, Pretoria

1901. ‡INGLIS, JOHN, LL.D. 4 Prince's-terrace, Dowanhill, Glasgow

1905. §Innes, R. T. A., F.R.A.S. Meteorological Observatory, Johannesburg.

1901. *Ionides, Stephen A. 929 Foster-building, Denver, Colorado

1912. §Irvine, Professor, J. C. The University, St. Andrews

1882. §IRVING, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts

1908. ‡Irwin, Alderman John. 33 Rutland-square, Dublin.

1876. *JACK, WILLIAM, LL.D., Professor of Mathematics in the University of Glasgow. 10 The University, Glasgow

1909. ‡Jacks, Professor L. P. 28 Holywell, Oxford.

Year of Election

1883. *Jackson, Professor A H , B Sc. 349 Collins-street, Melbourne, Australia
1903. ‡Jackson, C. S. Royal Military Academy, Woolwich, S.E.
1883. *Jackson, F. J 35 Leyland-road, Southport.
1883. ‡Jackson, Mrs. F. J. 35 Leyland-road, Southport.
1874. *Jackson, Frederick Arthur. Belmont, Somenos, Vancouver Island, B C., Canada
1899. ‡Jackson, Geoffrey A 31 Harrington-gardens, Kensington, S.W.
1906. *Jackson, James Thomas, M A. Engineering School, Trinity College, Dublin
1898 *Jackson, Sir John 51 Victoria-street, S.W.
1887 §Jacobson, Nathaniel, J.P. Olive Mount, Cheetham Hill-road, Manchester
1905 *Jaffé, Arthur, M A 3 King's Bench-walk, Temple, E C.
1874 *Jaffé, John Villa Jaffé, 38 Promenade des Anglais, Nice, France
1906. ‡Jalland, W. H Museum-street, York
1891. *James, Charles Henry, J P 64 Park-place, Cardiff
1891. *James, Charles Russell The Bungalow, Redhill, Surrey
1904 ‡James, Thomas Campbell University College, Aberystwyth.
1896 *Jameson, H Lyster, M A , Ph.D 18 Hillcroft-crescent, Ealing, W.
1859 *Jamieson, Thomas F , LL D , F G S Ellon, Aberdeenshire.
1889 *Japp, F R , M A , Ph D , LL D , F R S (Pres. B, 1898), Professor of Chemistry in the University of Aberdeen.
1910 *Japp, Henry, M Inst C E Care of Messrs. S. Pearson & Son, 507 Fifth Avenue, New York, U S A
1896 *Jarmay, Gustav Hartford Lodge, Hartford, Cheshire
1903 ‡Jarratt, J Ernest (Local Sec 1903) 10 Cambridge-road, Southport
1904 *Jeans, J H , M A , F R S Woodlands, Chaucer-road, Cambridge.
1897 ‡Jeffrey, E C., B A The University, Toronto, Canada
1912 §Jehu, T J , M A , M D , Professor of Geology in the University of St Andrews
1908 *Jenkin, Arthur Pearse, F R Met Soc Trewirgie, Redruth.
1909. *Jenkins, Miss Emily Vaughan Lyceum Club, 128 Piccadilly, W.
1903 ‡Jenkinson, J W The Museum, Oxford
1904 ‡Jenkinson, W W 6 Moorgate-street, E C
1893 §Jennings, G E 60 Fosse-road South, Leicester.
1905 ‡Jennings, Sydney P O Box 149, Johannesburg.
1905 ‡Jerome, Charles P O Box 83, Johannesburg.
Jessop, William Overton Hall, Ashover, Chesterfield.
1900 *Jevons, H Stanley, M A , B Sc Woodhill, Rhiwbeina, near Cardiff
1907 *Jevons, Miss H W 19 Chesterford-gardens, Hampstead, N W.
1905 §Jeyes, Miss Gertrude, B A Berrymead, 6 Lichfield-road, Kew Gardens
1909. *Johns, Cosmo, F G S , M.I M E. Burngrove, Pitsmoor-road, Sheffield
1884. ‡Johnson Alexander, M A , LL D 5 Prince of Wales-terrace, Montreal, Canada
1909. ‡Johnson, C. Kelsall, F.R.G S. The Glen, Sidmouth, Devon.
1890. *Johnson, Thomas, D Sc , F.L S , Professor of Botany in the Royal College of Science, Dublin.
1902. *Johnson, Rev. W , B.A , B Sc. Archbishop Holgate's Grammar School, York.
1898. *Johnson, W. Claude, M.Inst.C.E. Broadstone, Coleman's Hatch, Sussex.

Year of Election

1899. ‡JOHNSTON, Colonel Sir DUNCAN A, K.C.M G, C.B, R E, Hon Sec. R.G.S. (Pres. E, 1909.) Branksome, Saffrons-road, Eastbourne.
1883. ‡JOHNSTON, Sir H H, G C M G, K C B, F R G S St John's Priory, Poling, near Arundel
1909. *Johnston, J. Weir, M A. 20 Ely-place, Dublin.
1908. ‡Johnston, Swift Paine. 1 Hume-street, Dublin
1884. *Johnston, W H. County Offices, Preston, Lancashire
1885. ‡JOHNSTON-LAVIS, H. J, M D, F G S Beaulieu, Alpes-Maritimes, France.
1909. ‡Jolly, Professor W. A, M B., D.Sc. South African College, Cape Town.
1888. ‡JOLY, JOHN, M A, D Sc, F R S, F G S (Pres C, 1908), Professor of Geology and Mineralogy in the University of Dublin. Geological Department, Trinity College, Dublin
1904. §Jones, Miss E. E. Constance Girton College, Cambridge
1890. §JONES, Rev. EDWARD, F G S. Primrose Cottage, Embsay, Skipton
1896. ‡Jones, E Taylor, D Sc. University College, Bangor.
1903. §Jones, Evan Ty-Mawr, Aberdare
1907. *Jones, Mrs. Evan 39 Hyde Park-gate, S W.
1887. ‡Jones, Francis, F R S.E, F C S. Beaufort House, Alexandra Park, Manchester.
1891. *JONES, Rev G HARTWELL, D.D Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M A Inchyra House, 21 Cambridge-road, Waterloo, Liverpool
1912 §Jones, J H. The University, Glasgow
1905. ‡Jones, Miss Parnell The Rectory, Llanddewi Skyrrid, Abergavenny, Monmouthshire
1901. ‡Jones, R. E, J P Oakley Grange, Shrewsbury
1902. ‡Jones, R. M, M A Royal Academical Institution, Belfast
1908. ‡Jones, R Pugh, M A County School, Holyhead, Anglesey
1912. §Jones, W. Neilson University College, Reading
1875. *Jose, J E Ethersall, Tarbock-road, Huyton, Lancashire
1883. ‡Joyce, Rev A G, B A St John's Croft, Winchester
1886. ‡Joyce, Hon Mrs St John's Croft, Winchester
1905. ‡Judd, Miss Hilda M, B Sc Berrymead, 6 Lichfield-road, Kew
1870. ‡JUDD, JOHN WESLEY, C.B, LL D, F R S, F G S (Pres C, 1885, Council, 1886–92) Orford Lodge, 30 Cumberland-road, Kew.
1894 §Julian, Mrs Forbes Redholme, Braddon's Hill-road, Torquay.
1905. §Juritz, Charles F, M A, D Sc, F I C, Chief of the Division of Chemistry, Union of South Africa. Department of Agriculture, Cape Town.

1888. ‡Kapp, Gisbert, M.Inst C E, M Inst E E, Professor of Electrical Engineering in the University of Birmingham Pen-y-Coed, Pritchatts-road, Birmingham.
1904 ‡Kayser, Professor H The University, Bonn, Germany
1892. ‡KEANE, CHARLES A, Ph D. Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C.
1908. §KEEBLE, FREDERICK, M.A., Sc D. (Pres. K, 1912.), Professor of Botany in University College, Reading
1911. *Keith, Arthur, M.D, LL D, F.R C S. Royal College of Surgeons, Lincoln's Inn-fields, W C.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U S.A.
1908. ‡Kelly, Sir Malachy. Ard Brugh, Dalkey, Co Dublin.

Year of Election

1908. ‡Kelly, Captain Vincent Joseph. Montrose, Donnybrook, Co. Dublin.
1911. ‡Kelly, Miss. Montrose, Merton-road, Southsea.
1902. *Kelly, William J., J.P. 25 Oxford-street, Belfast.
1885. §KELTIE, J. SCOTT, LL.D., Sec. R.G.S., F.S.S. (Pres. E, 1897; Council, 1898–1904.) Royal Geographical Society, London, S.W.
1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1898. *Kemp, John T., M.A. 4 Cotham-grove, Bristol.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1891. ‡KENDALL, PERCY F., M.Sc., F.G.S., Professor of Geology in the University of Leeds.
1875. ‡KENNEDY, Sir ALEXANDER B. W., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1894.) 1 Queen Anne-street, Cavendish-square, W.
1897. §Kennedy, George, M.A., LL.D., K.C. Crown Lands Department, Toronto, Canada.
1906. ‡Kennedy, Robert Sinclair. Glengall Ironworks, Millwall, E.
1908. ‡Kennedy, William. 40 Trinity College, Dublin.
1905. *Kennerley, W. R. P.O. Box 158, Pretoria.
1913. §KENRICK, Sir G. H. (LOCAL TREASURER, 1913.) Whetstone, Somerset-road, Edgbaston, Birmingham.
1913. §KENRICK, W. BYNG. (LOCAL SECRETARY, 1913.) Metchley House, Somerset-road, Edgbaston, Birmingham.
1893. §KENT, A. F. STANLEY, M.A., F.L.S., F.G.S., Professor of Physiology in the University of Bristol.
1901. ‡Kent, G. 16 Premier-road, Nottingham.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1881. ‡KERMODE, P. M. C. Claghbene, Ramsey, Isle of Man.
1909. ‡Kerr, Hugh L. 68 Admiral-road, Toronto, Canada.
1892. ‡KERR, J. GRAHAM, M.A., F.R.S., Regius Professor of Zoology in the University of Glasgow.
1889. ‡Kerry, W. H. R. The Sycamores, Windermere.
1910. §Kershaw, J. B. C. West Lancashire Laboratory, Waterloo, Liverpool.
1869. *Kesselmeyer, Charles Augustus. Roseville, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Edelweiss Villa, Albert-road, Hale, Cheshire.
1903. ‡Kewley, James. Balek Papan, Koltei, Dutch Borneo.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1902. ‡*Kidd, George. Greenhaven, Malone Park, Belfast.*
1906. ‡Kidner, Henry, F.G.S. 25 Upper Rock-gardens, Brighton.
1886. §KIDSTON, ROBERT, LL.D., F.R.S., F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1901. *Kiep, J. N. 137 West George-street, Glasgow.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1896. *Killey, George Deane, J.P. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. ‡KIMMINS, C. W., M.A., D.Sc. Dame Armstrong House, Harrow.
1875. *KINCH, EDWARD, F.I.C., Professor of Chemistry in the Royal Agricultural College, Cirencester.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1883. *King, John Godwin. Stonelands, East Grinstead.
1883. *King, Joseph, M.P. Sandhouse, Witley, Godalming.

Year of Election

1908. §King, Professor L A L., M.A. St. Mungo's College Medical School, Glasgow.
1860. *King, Mervyn Kersteman Merchants' Hall, Bristol.
1875. *King, Percy L. 15 The Avenue, Clifton, Bristol.
1912. *King, W. B. R. Nelholme, Grimston-avenue, Folkestone.
1912. §King, W. J. Harding. 25 York House, Kensington, W
1870. ‡King, William, M Inst C E 5 Beach-lawn, Waterloo, Liverpool.
1909. ‡Kingdon, A 197 Yale-avenue, Winnipeg, Canada.
1903 ‡Kingsford, H. S., M A 8 Elsworthy-terrace, N.W.
1900 ‡KIPPING, Professor F. STANLEY, D Sc, Ph D, F R S. (Pres B, 1908) University College, Nottingham.
1899. *Kirby, Miss C F. 8 Windsor-court, Moscow-road, W.
1901. §Kitto, Edward. The Observatory, Falmouth
1886. ‡Knight, Captain J M, F G S. Bushwood, Wanstead, Essex
1905 ‡Knightley, Lady, of Fawsley Fawsley Park, Daventry
1912. §Knipe, Henry R, F L S, F G S. 9 Linden-park, Tunbridge Wells.
1888. ‡KNOTT, Professor CARGILL G, D Sc, F R S E. 42 Upper Gray-street, Edinburgh
1887. *Knott, Herbert, J P Sunnybank, Wilmslow, Cheshire
1887. *Knott, John F Edgemoor, Burbage, Derbyshire.
1906. *Knowles, Arthur J, B A., M Inst C E Turf Club, Cairo, Egypt.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co Antrim
1902. ‡KNOX, R KYLE, LL D 1 College-gardens, Belfast
1875. *Knubley, Rev. E. P, M A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1890. *Krauss, John Samuel, B A Stonycroft, Knutsford-road, Wilmslow, Cheshire
1888 *Kunz, G F, M A, Ph D Care of Messrs Tiffany & Co, 11 Union-square, New York City, U S A.

1903 *Lafontaine, Rev H C de 49 Albert-court, Kensington Gore, S W.
1909. ‡Laird, Hon. David. Indian Commission, Ottawa, Canada.
1904 ‡Lake, Philip. St John's College, Cambridge
1904 ‡Lamb, C G. Ely Villa, Glisson-road, Cambridge
1889 *Lamb, Edmund, M.A Borden Wood, Liphook, Hants
1887. ‡LAMB, HORACE, M.A, LL D, D Sc, F R S (Pres A, 1904), Professor of Pure Mathematics in the Victoria University, Manchester 6 Wilbraham-road, Fallowfield, Manchester
1903 ‡*Lambert, Joseph. 9 Westmoreland-road, Southport.*
1893 *LAMPLUGH, G W, F R S, F G S (Pres C, 1906) 13 Beaconsfield-road, St. Albans
1898 *LANG, WILLIAM H, F.R S 2 Heaton-road, Withington, Manchester.
1886. *LANGLEY, J N, M.A, D Sc, F.R S (Pres I, 1899; Council, 1904–07), Professor of Physiology in the University of Cambridge. Trinity College, Cambridge
1865. ‡LANKESTER, Sir E. RAY, K C.B, M A, LL.D, D Sc, F R.S. (PRESIDENT, 1906; Pres. D, 1883; Council, 1889–90, 1894–95, 1900–02) 29 Thurloe-place, S W.
1880. *LANSDELL, Rev HENRY, D D, F R.A S, F.R.G S. Morden College, Blackheath, London, S E
1884. ‡Lanza, Professor G. Massachusetts Institute of Technology, Boston, U S.A.
1911. ‡Lapthorn, Miss. St Bernards, Grove-road South, Southsea.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R S., F.G.S. (Pres. C, 1892), Professor of Geology and Physiography in the University of Birmingham, 38 Calthorpe-road, Edgbaston, Birmingham.

Year of Election

1909. §Larard, C. E., Assoc M Inst C E. 106 Cranley-gardens, Muswell Hill, N

1887. ‡Larmor, Alexander Craglands, Helen's Bay, Co. Down.

1881. ‡LARMOR, SIR JOSEPH, M A , D Sc , Sec R S (Pres A, 1900), Lucasian Professor of Mathematics in the University of Cambridge. St John's College, Cambridge

1883. ‡Lascelles, B P., M A Headland, Mount Park, Harrow.

1870. *LATHAM, BALDWIN, M Inst C E , F G S. Parliament-mansions, Westminster, S W.

1911 §Lattey, R. T. Royal Naval College, Dartmouth

1900. ‡Lauder, Alexander, Lecturer in Agricultural Chemistry in the Edinburgh and East of Scotland College of Agriculture, Edinburgh

1911. §Laurie, Miss C L. 1 Vittoria-walk, Cheltenham.

1892 ‡LAURIE, MALCOLM, B A , D Sc , F.L S School of Medicine, Surgeons' Hall, Edinburgh.

1883. ‡Laurie, Lieut -General 47 Porchester-terrace, W.

1907. *Laurie, Robert Douglas. Department of Zoology, The University, Liverpool.

1870. *Law, Channell Ilsham Dene, Torquay

1905 ‡Lawrence, Miss M Roedean School, near Brighton.

1911. *Lawson, A Anstruther, D.Sc , F R S E , F L S The University, Glasgow.

1908 §Lawson, H S , B A Buxton College, Derbyshire

1908 ‡Lawson, William, LL D 27 Upper Fitzwilliam-street, Dublin

1888 ‡Layard, Miss Nina F , F L S Rookwood, Fonnereau-road, Ipswich.

1883 *Leach, Charles Catterall Seghill, Northumberland

1894. *LEAHY, A H , M A , Professor of Mathematics in the University of Sheffield 92 Ashdell-road, Sheffield

1905 ‡Leake, E O 5 Harrison-street, Johannesburg.

1901 *Lean, George, B Sc. 15 Park-terrace, Glasgow

1904. *Leathem, J G St John's College, Cambridge

1884 *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U S A

1872 ‡LEBOUR, G A , M A , D Sc , Professor of Geology in the Armstrong College of Science, Newcastle-on-Tyne

1910 §Lebour, Miss M. V , M Sc. Zoological Department, The University, Leeds.

1912 §Lechmere, A Eckley, M Sc. Townhope, Hereford.

1895 *Ledger, Rev. Edmund Protea, Doods-road, Reigate

1907 ‡Lee, Mrs Barton 126 Mile End-lane, Stockport

1910. *Lee, Ernest Birkbeck College, Chancery-lane, E C.

1896 §Lee, Rev H J Barton 126 Mile End-lane, Stockport

1909. §Lee, I. L Care of the Pennsylvania Railroad Company, Broad-street Station, Philadelphia, U S A.

1909. †Lee, Rev. J. W., D.D. 5068 Washington-avenue, St. Louis, Missouri, U S.A.

1894. *Lee, Mrs W. The Nook, Forest Row, Sussex.

1909. ‡Leeming, J. H., M.D. 406 Devon-court, Winnipeg, Canada.

1905. ‡*Lees, Mrs. A. P. Care of Dr Norris Wolfenden, 76 Wimpole-street, W.*

1892. *LEES, CHARLES H., D.Sc., F.R.S., Professor of Physics in the East London College, Mile End. Greenacres, Woodside-road, Woodford Green, Essex.

1912. §Lees, John. Pitscottie, Cupar, Fife.

1886. *Lees, Lawrence W. Old Ivy House, Tettenhall, Wolverhampton.

1906. ‡Lees, Robert. Victoria-street, Fraserburgh.

Year of Election

1889. *Leeson, John Rudd, M D, C.M, F L S., F.G S Clifden House, Twickenham, Middlesex.
1906. ‡Leetham, Sidney. Elm Bank, York.
1912. §LEGGAT, W. G. Bank of Scotland, Dundee.
1912. §Legge, James G., Municipal Buildings, Liverpool.
1910. §Leigh, H. S. Brentwood, Worsley, near Manchester.
1891 ‡Leigh, W W. Glyn Bargoed, Treharris, R S O, Glamorganshire.
1903 ‡Leighton, G R, M D, F R S E, Professor of Pathology in the Royal Veterinary College, Edinburgh
1906. ‡Leiper, Robert T, M B, F.Z S London School of Tropical Medicine, Royal Albert Dock, E.
1905 ‡Leitch, Donald P.O. Box 1703, Johannesburg
1903 *Lempfert, R G K, M A 66 Sydney-street, S W
1908 ‡Lentaigne, John 42 Merrion-square, Dublin
1887 *Leon, John T, M D, B Sc 23 Grove road, Southsea
1901 §LEONARD, J H, B Sc 13 Gunterstone road, West Kensington, W.
1912 *Lessner, C B, Assoc M Inst C E, F C S Curil, Spain
1890. *Lester, Joseph Henry 5 Grange-drive, Monton Green, Manchester.
1904 *Le Sueur, H R, D Sc Chemical Laboratory, St Thomas's Hospital, S E
1900 ‡Letts Professor E A, D Sc, F R S E Queen's University, Belfast
1896 ‡Lever, Sir W H, Bart. Thornton Manor, Thornton Hough, Cheshire.
1887. *Levinstein, Ivan Hawkesmoor, Fallowfield, Manchester.
1893 *LEWES, VIVIAN B, F C S, Professor of Chemistry in the Royal Naval College, Greenwich, S E
1904 *Lewis, Mrs Agnes S, LL D Castle Brae, Chesterton-lane, Cambridge
1870 ‡LEWIS, ALFRED LIONEL 35 Beddington-gardens, Wallington, Surrey
1891. ‡Lewis, Professor D Morgan, M A University College, Aberystwyth.
1899. ‡Lewis, Professor E P University of California, Berkeley, U S A.
1910. §LEWIS, FRANCIS J, D Sc, F L S Department of Biology, University of Alberta, Edmonton, Alberta, Canada
1904 ‡Lewis, Hugh Glanafrau, Newtown, Montgomeryshire
1910. *Lewis, T C West Home, West-road, Cambridge
1911 §Lewis, W C McC, M A, D.Sc University College, W C
1903 ‡Lewkowitsch, Dr J 71 Priory-road, N W
1906. ‡Liddiard, James Edward, F.R G S. Rodborough Grange, Bournemouth
1908. ‡Lilly, W E, M A, Sc D 39 Trinity College, Dublin.
1904 ‡Link, Charles W 14 Chichester-road, Croydon
1898. ‡Lippincott, R. C Cann Over Court, near Bristol
1888. ‡LISTER, J J, M A, F R S (Pres D, 1906) St John's College, Cambridge.
1861. *LIVEING, G. D, M A, F R.S. (Pres B, 1882; Council 1888–95; Local Sec 1862) Newnham, Cambridge
1876. *LIVERSIDGE, ARCHIBALD, M A, F R S, F C S, F G S., F R G S Hornton Cottage, Hornton-street, Kensington, W.
1902. §Llewellyn, Evan Working Men's Institute and Hall Blaenavon
1912. §Lloyd, Miss Dorothy Jordan Newnham College, Cambridge.
1909. §Lloyd, George C, Secretary of the Iron and Steel Institute. 28 Victoria-street, S.W
1903. ‡Lloyd, Godfrey I H The University of Toronto, Canada.
1854 *LOBLEY, J LOGAN, F G S, F R G S 36 Palace-street, Buckingham Gate, S W

Year of Election

1892. ‡Loch, C S, D.C.L. Denison House, Vauxhall Bridge-road, S.W.
1905. ‡Lochrane, Miss T 8 Prince's-gardens, Dowanhill, Glasgow.
1904. ‡Lock, Rev. J. B. Herschel House, Cambridge.
1863. ‡Lockyer, Sir J. Norman, K.C B, LL D., D.Sc., F.R S (President, 1903; Council, 1871–76, 1901–02) 16 Penywern-road, S.W.
1902. *Lockyer, Lady. 16 Penywern-road, S W.
1900. §Lockyer, W. J S, Ph D 16 Penywern-road, S W.
1886. *Lodge, Alfred, M A. The Croft, Peperharow-road, Godalming
1875. *Lodge, Sir Oliver J., D Sc, LL D, F R S (Pres A, 1891; Council, 1891–97, 1899-1903, 1912–), Principal of the University of Birmingham.
1894. **Lodge, Oliver W. F.* 17 *Ruskin-buildings, Westminster, S.W.*
1899 §Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1902. ‡Londonderry, The Marquess of, K G. Londonderry House, Park-lane, W
1903 ‡Long, Frederick. The Close, Norwich.
1905. ‡Long, W F. City Engineer's Office, Cape Town
1883. *Long, William Thelwall Heys, near Warrington
1910 *Londgen, G A Stanton-by-Dale, Nottingham
1904. *Longden, J A, M Inst C E Chislehurst, Marlborough-road, Bournemouth.
1905. ‡Longden, Mrs. J B Chislehurst, Marlborough-road, Bournemouth
1898 *Longfield, Miss Gertrude Belmont, High Halstow, Rochester
1901. *Longstaff, Captain Frederick V, F R G S No 1252 Post Office, Victoria, B C, Canada
1875 *Longstaff, George Blundell, M A, M D, F C S, F S S Highlands, Putney Heath, S W
1872. *Longstaff, Lieut-Colonel Llewellyn Wood, F R G S Ridgelands, Wimbledon, S W
1881 *Longstaff, Mrs Ll W Ridgelands, Wimbledon, S W
1899. *Longstaff, Tom G, M A, M D 93 Whitehall-court, S W.
1903. ‡Loton, John, M A 23 Hawkshead-street, Southport.
1897 ‡Loudon, James, LL D, President of the University of Toronto, Canada
1883. *Louis, D A, F G.S, F I C 123 Pall Mall, S W.
1896 ‡Louis, Henry, D.Sc, Professor of Mining in the Armstrong College of Science, Newcastle-on-Tyne
1887. *Love, A. E H, M A, D Sc, F R S (Pres. A, 1907), Professor of Natural Philosophy in the University of Oxford. 34 St Margaret's-road, Oxford
1886. *Love, E F J., M A, D.Sc. The University, Melbourne, Australia
1904. *Love, J. B., LL D. Outlands, Devonport
1876. *Love, James, F R A S, F G S, F Z S. 33 Clanricarde-gardens, W
1908 §Low, Alexander, M.A, M D The University, Aberdeen.
1909. ‡Low, David, M.D 1927 Scarth-street, Regina, Saskatchewan, Canada.
1912 §Low, William Balmakewan, Seaview, Monifieth
1885. §Lowdell, Sydney Poole Baldwin's Hill, East Grinstead, Sussex
1891. §Lowdon, John. St. Hilda's, Barry, Glamorgan.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1886. *Lowe, John Landor, B.Sc., M Inst.C E. Spondon, Derbyshire.
1894. ‡Lowenthal, Miss Nellie Woodside, Egerton, Huddersfield
1903. *Lowry, Dr T. Martin. 130 Horseferry-road, S W.
1901. *Lucas, Keith. Trinity College, Cambridge.
1891. *Lucovich, Count A Tyn-y-parc, Whitchurch, near Cardiff
1906. §Ludlam, Ernest Bowman. College Gate, 32 College-road, Clifton, Bristol.

Year of Election

1866. *Lund, Charles. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1883. *Lupton, Arnold, M.P., M.Inst C E, F.G S. 7 Victoria-street, S.W.
1874. *LUPTON, SYDNEY, M.A. (Local Sec. 1890.) 102 Park-street, Grosvenor-square, W
1898. §Luxmoore, Dr. C. M, F.I.C., 19 Disraeli-gardens, Putney, S.W.
1903. ‡Lyddon, Ernest H Lisvane, near Cardiff.
1871. ‡Lyell, Sir Leonard, Bart, F.G.S. Kennordy, Kirriemuir
1884 ‡Lyman, H H. 384 St Paul-street, Montreal, Canada
1912. *Lynch, Arthur, M A, M P. 80 Antrim-mansions, Haverstock Hill, N.W
1907. *LYONS, Captain HENRY GEORGE, D Sc, F R S (Council, 1912–) 5 Heathview-gardens, Roehampton, S W
1908. ‡Lyster, George H 34 Dawson-street, Dublin
1908. ‡Lyster, Thomas W, M A. National Library of Ireland, Kildare-street, Dublin

1905. ‡Maberly, Dr John. Shirley House, Woodstock, Cape Colony.
1868. ‡MACALISTER, ALEXANDER, M A, M.D, F R S. (Pres H, 1892; Council, 1901–06), Professor of Anatomy in the University of Cambridge Torrisdale, Cambridge
1878. ‡MACALISTER, Sir DONALD, K C B, M A, M D., LL D, B Sc, Principal of the University of Glasgow
1904 †Macalister, Miss M A M Torrisdale, Cambridge.
1908. ‡Macallan, J, F I C, F R S E 3 Rutland-terrace, Clontarf, Co. Dublin.
1896. ‡MACALLUM, Professor A B, Ph D, D Sc, F R S (Pres. I, 1910, Local Sec. 1897) 59 St George-street, Toronto, Canada
1879 §MacAndrew, James J, F L S Lukesland, Ivybridge, South Devon
1883. ‡MacAndrew, Mrs J J Lukesland, Ivybridge, South Devon
1909. ‡MacArthur, J. A., M D. Canada Life Building, Winnipeg, Canada.
1896. *Macaulay, F S, M A 19 Dewhurst-road, W
1904. *Macaulay, W H King's College, Cambridge
1896 ‡MACBRIDE, Professor E W, M A, D Sc, F R S. Imperial College of Science and Technology, S W.
1902. *Maccall, W. T, M Sc Technical College, Sunderland.
1912. §McCallum, George Fisher 45 Sherbrooke-avenue, Glasgow.
1912. §McCallum, Mrs Lizzie 45 Sherbrooke-avenue, Glasgow.
1886. ‡MacCarthy, Rev. E. F. M, M A 50 Harborne-road, Edgbaston, Birmingham.
1908. §McCarthy, Edward Valentine, J P. Ardmanagh House, Glenbrook, Co. Cork
1909. ‡McCarthy, J. H. Public Library, Winnipeg, Canada.
1884. *McCarthy, J J, M D. 11 Wellington-road, Dublin
1887. *McCarthy, James. 1 Sydney-place, Bath.
1904. §McClean, Frank Kennedy Rusthall House, Tunbridge Wells.
1902. ‡McClelland, J A, M A., F.R.S., Professor of Physics in University College, Dublin.
1906. ‡McClure, Rev. E. 80 Eccleston-square, S W.
1878. *M'Comas, Henry. 12 Elgin-road, Dublin
1908. §McCombie, Hamilton, M A, Ph D The University, Birmingham.
1901. *MacConkey, Alfred Lister Lodge, Elstree, Herts.
1901. ‡MacCormac, J M, M.D 31 Victoria-place, Belfast
1901. ‡McCrae, John, Ph D 7 Kirklee-gardens, Glasgow
1912. §MacCulloch, Rev. Canon J. A, D.D. The Rectory, Bridge of Allan.
1905. §McCulloch, Principal J D Free College, Edinburgh.

Year of Election

1904 ‡McCulloch, Major T, R A. 68 Victoria-street, S.W.
1909. ‡MacDonald, Miss Eleanor. Fort Qu'Appelle, Saskatchewan, Canada.
1904 ‡MACDONALD. H M, M.A, F.R S., Professor of Mathematics in the University of Aberdeen
1905. ‡McDonald, J G P.O Box 67, Bulawayo
1900. ‡MacDonald, J. Ramsay, M P. 3 Lincoln's Inn-fields, W.C.
1905. §MACDONALD, J. S., B A (Pres I, 1911), Professor of Physiology in the University of Sheffield.
1884. *Macdonald, Sir W C 449 Sherbrooke-street West, Montreal, Canada.
1909. ‡MacDonell, John, M.D. Portage-avenue, Winnipeg, Canada.
1909. *MacDougall, R. Stewart. The University, Edinburgh.
1912. §McDougall, Dr W, F R S Woodsend, Foxcombe Hill, near Oxford
1908 ‡McEwen, Walter, J P Flowerbank, Newton Stewart, Scotland.
1897. ‡McEwen, William C 9 South Charlotte-street, Edinburgh.
1881. ‡Macfarlane, Alexander, D Sc., F R S.E. 317 Victoria-avenue, Chatham, Ontario, Canada
1906. §McFarlane, John, M A. 30 Parsonage-road, Withington, Manchester.
1885. ‡Macfarlane, J. M, D Sc, F R S E, Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co, Pennsylvania, U S A
1901 ‡Macfee, John 5 Greenlaw-terrace, Paisley
1909 ‡Macgachen, A F. D. 281 River-avenue, Winnipeg, Canada
1888. ‡MacGeorge, James 8 Matheson-road, Kensington, W.
1908 ‡McGRATH, Sir JOSEPH, LL D. (Local Sec 1908) Royal University of Ireland, Dublin
1908. §McGregor, Charles Training Centre, Charlotte-street, Aberdeen.
1906. ‡MACGREGOR, D H, M A. Trinity College, Cambridge
1884. *MACGREGOR, JAMES GORDON, M A, D Sc., F R S, F.R S.E., Professor of Natural Philosophy in the University of Edinburgh
1902 ‡*McIlroy, Archibald Glenvale, Drumbo, Lisburn, Ireland*
1867. *MCINTOSH, W C, M D, LL D, F.R S, F R S E, F.L.S (Pres. D, 1885), Professor of Natural History in the University of St Andrews 2 Abbotsford-crescent, St Andrews, N B
1909. ‡McIntyre, Alexander. 142 Maryland-avenue, Winnipeg, Canada.
1909. ‡McIntyre, Daniel. School Board Offices, Winnipeg, Canada.
1912 §McIntyre, J Lewis, M A, D Sc Abbotsville, Cults, Aberdeenshire
1909. ‡McIntyre, W. A. 339 Kennedy-street, Winnipeg, Canada.
1884 §MacKay, A. H, B Sc, LL D, Superintendent of Education Education Office, Halifax, Nova Scotia, Canada
1885. ‡MACKAY, JOHN YULE, M D, LL D, Principal of and Professor of Anatomy in University College, Dundee
1912 §Mackay, R J 27 Arkwright-road, Hampstead, N W
1908. ‡McKay, William, J P Clifford-chambers, York.
1909. §McKee, Dr E S Grand and Nassau-streets, Cincinnati, U.S.A.
1873 ‡MCKENDRICK, JOHN G, M D, LL D, F R S, F.R.S.E (Pres I, 1901; Council, 1903-09), Emeritus Professor of Physiology in the University of Glasgow Maxieburn, Stonehaven, N.B.
1909. ‡McKenty, D. E. 104 Colony-street, Winnipeg, Canada.
1907. ‡MCKENZIE, ALEXANDER, M A, D Sc, Ph D. Birkbeck College, Chancery-lane, W C
1905. ‡Mackenzie, Hector. Standard Bank of South Africa, Cape Town
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1910. ‡Mackenzie, K. J. J., M A. 10 Richmond-road, Cambridge.
1909. §MacKenzie, Kenneth. Royal Alexandra Hotel, Winnipeg, Canada.

Year of Election

1901. *Mackenzie, Thomas Brown Netherby, Manse-road, Motherwell, N B.
1912. §Mackenzie, William, J P. Harecraig, Broughty Ferry.
1872. *Mackey, J. A. United University Club, Pall Mall East, S.W.
1901. ‡Mackie, William, M D 13 North-street, Elgin.
1887 ‡MACKINDER, H J, M A., M P., F R G S (Pres E, 1895; Council, 1904 1905.) 243 St. James's-court, Buckingham-gate, S.W.
1911. §Mackinnon, Miss D L. 302 Blackness-road, Dundee
1893. *McLaren, Mrs E L Colby, M B, Ch B. 133 Tettenhall-road, Wolverhampton.
1901. ‡Maclaren, J. Malcolm Royal Colonial Institute, Northumberland Avenue, W C
1905 ‡McLaren, Thomas P O Box 1034, Johannesburg
1901. ‡Maclay, William Thornwood, Langside, Glasgow
1901. ‡McLean Angus, B Sc Harvale, Meikleriggs, Paisley.
1892. *MACLEAN, MAGNUS, M A, D Sc, F R S E (Local Sec 1901), Professor of Electrical Engineering, Technical College, Glasgow
1909. ‡MacLean, Neil Bruce. 24 Hitchcock Hall, The University, Chicago, U.S A.
1912 §McLean, R C, B Sc 36 Avenue-road, Highgate, N
1908 §McLennan, J C, Professor of Physics in the University of Toronto, Canada
1868 §McLEOD, HERBERT, LL D, F R S (Pres B, 1892, Council, 1885–90) 37 Montague-road, Richmond Surrey
1909 ‡MacLeod, M. H. C N R. Dep t, Winnipeg, Canada
1883 ‡MACMAHON, Major PERCY A, D Sc, LL D, F R S (GENERAL SECRETARY, 1902– ; Pres A, 1901, Council, 1898–1902) 27 Evelyn-mansions, Carlisle-place, S W
1909. ‡McMILLAN, The Hon. Sir DANIEL H., K.C M G. Government House, Winnipeg, Canada.
1902 ‡McMordie, Robert J Cabin Hill, Knock, Co Down
1878 ‡Macnie, George 59 Bolton-street, Dublin
1905 §Macphail, Dr S Rutherford Rowditch, Derby
1909. ‡MacPhail, W. M P O Box 88, Winnipeg, Canada
1907. ‡Macrosty, Henry W 29 Hervey-road, Blackheath, S E
1906 ‡Macturk, G W B 15 Bowlalley-lane, Hull
1908 ‡McVittie, R B, M D 62 Fitzwilliam-square North, Dublin
1908. ‡McWalter, J C, M D, M A 19 North Earl-street, Dublin
1902 ‡McWeeney, Professor E J, M D 84 St Stephen's-green, Dublin.
1910 ‡McWilliam, Dr Andrew Kalimate, B N R, near Calcutta
1908. ‡MADDEN, Rt. Hon Mr Justice Nutley, Booterstown, Dublin.
1905 ‡Magenis, Lady Louisa 34 Lennox-gardens, S W
1909. ‡Magnus, Laurie, M.A. 12 Westbourne terrace, W.
1875. *MAGNUS, Sir PHILIP, B Sc, B A, M P (Pres. L, 1907). 16 Gloucester-terrace, Hyde Park, W
1908. *Magson, Egbert H. Westminster College, Horseferry-road, S W.
1907. *Mair, David Civil Service Commission, Burlington-gardens, W
1908 *Makower, W The University, Manchester
1857 ‡MALLET, JOHN WILLIAM, Ph D, M D, F R S, F C S The University of Virginia, Albemarle Co, U S A
1912. §Malloch, James, M A, F S A. (Scot) Training College, Dundee
1905 ‡Maltby, Lieutenant G R, R N 54 St George's-square, S W
1897. ‡MANCE, Sir H C Old Woodbury, Sandy, Bedfordshire
1912 §Manhaut, James Holborn Hall, Gray's Inn-road, W C
1903. ‡Manifold, C C 16 St James's-square, S W
1894. ‡Manning, Percy, M A, F S A Watford, Herts
1887. *March, Henry Colley, M D, F S A. Portesham, Dorchester, Dorsetshire.

Year of Election

1902. *MARCHANT, Dr. E W. The University, Liverpool.
1898. *Mardon, Heber 2 Litfield-place, Clifton, Bristol.
1911. *Marett, R. R. Exeter College, Oxford.
1900 ‡Margerison, Samuel Calverley Lodge, near Leeds.
1864. ‡MARKHAM, Sir CLEMENTS R, K.C B, F R S, F R.G.S., F.S.A. (Pres E. 1879; Council, 1893-96) 21 Eccleston-square, S.W.
1905. §Marks, Samuel P O Box 379, Pretoria
1881. *MARR, J E, M A, D Sc, F R S, F G S. (Pres C, 1896; Council, 1896-1902, 1910-) St John's College, Cambridge.
1903 ‡Marriott, William Royal Meteorological Society, 70 Victoria-street, S W.
1892. *Marsden-Smedley, J B Lea Green, Cromford, Derbyshire
1883. *Marsh, Henry Carpenter 3 Lower James-street, Golden-square, W
1887. ‡Marsh. J E, M A, F R S. University Museum, Oxford.
1889. *MARSHALL, ALFRED, M A, LL D, D Sc. (Pres F, 1890) Balliol Croft, Madingley-road, Cambridge
1912. §Marshall, Professor C R, M A, M D. The Medical School, Dundee
1904. ‡Marshall, F H A University of Edinburgh
1905. ‡Marshall, G A K 6 Chester-place, Hyde Park-square, W.
1892 §MARSHALL, HUGH, D Sc, F R S, F R S E, Professor of Chemistry in University College, Dundee.
1901. ‡*Marshall, Robert* 97 *Wellington-street, Glasgow*
1907. ‡Marston, Robert 14 Ashleigh-road, Leicester.
1899. §Martin, Miss A M. Park View, 32 Bayham-road, Sevenoaks.
1911. §MARTIN, CHARLES JAMES, M B, D Sc, F R.S. Lister Institute, Chelsea-gardens, S.W.
1884 §Martin, N H, J P, F R S E, F L S. Ravenswood, Low Fell, Gateshead
1889. *Martin, Thomas Henry, Assoc M Inst C E Windermere, Mount Pleasant-road, Hastings
1912. ‡MARTIN, W. H. BLYTH. (Local Sec 1912) City Chambers, Dundee
1911. §Martindell, E W, M.A. Royal Anthropological Institute, 50 Great Russell-street, W C.
1907. ‡Masefield, J. R B, M A Rosehill, Cheadle, Staffordshire
1905 *Mason, Justice A W. Supreme Court, Pretoria
1893. *Mason, Thomas Enderleigh, Alexandra Park, Nottingham
1913. §Mason, William. Engineering Laboratory, The University, Liverpool
1891. *Massey, William H, M Inst C E Twyford, R S O, Berkshire.
1885. ‡Masson, David Orme, D Sc, F.R.S., Professor of Chemistry in the University of Melbourne.
1910 ‡Masson, Irvine, M Sc. 11 Chester-street, Edinburgh.
1905. §Massy, Miss Mary. 3 Carlton-place, Teignmouth, Devon
1901. *Mather, G. R. Boxlea, Wellingborough
1910. *Mather, Thomas, F R S., Professor of Electrical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W.
1887. *Mather, Right Hon. Sir William, M Inst C E. Salford Iron Works, Manchester
1909. ‡Mathers, Mr. Justice. 16 Edmonton-street, Winnipeg, Canada.
1908. ‡Matheson, Sir R E, LL D Charlemont House, Rutland-square, Dublin.
1894. ‡MATHEWS, G. B., M.A., F R S. 10 Menai View, Bangor, North Wales.
1902. ‡MATLEY, C A, D.Sc. Morningside, Egmont-road, Sutton, Surrey.

Year of Election

1904. ‡Matthews, D. J. The Laboratory, Citadel Hill, Plymouth.
1911. ‡Matthey, George, F.R.S Cheyne House, Chelsea Embankment, S.W.
1899. *Maufe, Herbert B, B A., F G.S. P.O Box 168, Bulawayo, Rhodesia.
1893. ‡Mavor, Professor James. University of Toronto, Canada.
1894. §Maxim, Sir Hiram S. Thurlow Park, Norwood-road, West Norwood, S E.
1905. §Maylard, A Ernest. 12 Blythswood-square, Glasgow.
1905. ‡Maylard, Mrs. 12 Blythswood-square, Glasgow
1878. *Mayne, Thomas. 19 Lord Edward-street, Dublin.
1904 ‡Mayo, Rev. J, LL D. 6 Warkworth-terrace, Cambridge
1912. §Meek, Alexander, M Sc, Professor of Zoology in the Armstrong College of Science, Newcastle-on-Tyne
1879 §Meiklejohn, John W. S, M D 105 Holland-road, W.
1905 ‡Mein, W. W. P O Box 1145, Johannesburg
1881. *Meldola, Raphael, D Sc, LL D, F R S, F C S, F I C, F.R A.S., F E S, Officier de l'Instr Publ France (Pres. B, 1895; Council, 1892–99, 1911–), Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W C
1908. ‡Meldrum, A N, D Sc. Chemical Department, The University, Manchester
1883. ‡Mellis, Rev James 23 Part-street. Southport
1879. *Mellish, Henry. Hodsock Priory, Worksop
1866 ‡Mello, Rev. J. M, M A, F G S Cliff Hill, Warwick.
1881. §Melrose, James Clifton Croft, York.
1905. *Melvill, E. H V., F.G S., F R G S. P O. Val, Standerton District, Transvaal.
1909. ‡Menzies, Rev. James, M D Hwaichingfu, Honan, China.
1905. ‡Meredith, H. O, M.A, Professor of Economics in Queen's University, Belfast.
1879. ‡Merivale, John Herman, M A (Local Sec 1889) Togston Hall, Acklington
1899. *Merrett, William H, F I C. Hatherley, Grosvenor-road. Wallington, Surrey.
1899. ‡Merryweather, J. C 4 Whitehall-court, S W
1884. *Merthyr, The Right Hon Lord, K C V O The Mardy, Aberdare
1889. *Merz, John Theodore The Quarries, Newcastle-upon-Tyne.
1905. ‡Methven, Cathcart W. Club Arcade, Smith-street, Durban.
1896. ‡Metzler, W. H., Ph.D., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S A
1869. ‡Miall, Louis C., D Sc, F R S, F.L.S, F G S (Pres D, 1897; Pres L, 1908; Local Sec. 1890.) Norton Way North, Letchworth.
1903. *Micklethwait, Miss Frances M. G. 15 St Mary's-square, Paddington, W.
1912. §Middlemore, Thomas, B A. Malsetter, Orkney
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D, Bishop of. Bishop's House, Middlesbrough
1904. ‡Middleton, T. H, M.A. (Pres M, 1912) Board of Agriculture and Fisheries, 4 Whitehall-place, S W.
1894. *Miers, Sir H A, M.A., D.Sc., F.R.S., F G S (Pres C, 1905; Pres. L, 1910), Principal of the University of London. 23 Wetherby-gardens, S.W
1885. §Mill, Hugh Robert, D Sc, LL.D, F.R S E., F R.G.S (Pres. E, 1901.) 62 Camden-square, N.W
1905. ‡Mill, Mrs. H. R. 62 Camden-square, N W

Year of Election

1912. §MILLAR, Dr. A. H. (Local Sec 1912). Albert Institute, Dundee
1889 *MILLAR, ROBERT COCKBURN. 30 York-place, Edinburgh.
1909. §Miller, A. P Quibell, Ontario, Canada
1895. ‡Miller, Thomas, M Inst C E 9 Thoroughfare, Ipswich
1909. ‡Miller, Professor W. G. Bureau of Mines, Toronto, Canada.
1904 ‡Millis, C T Hollydene, Wimbledon Park-road, Wimbledon.
1905 §Mills, Mrs A A Ceylon Villa, Blinco-grove, Cambridge
1908. ‡Mills, Miss E A Nurney, Glenagarey, Co Dublin.
1868 *MILLS, EDMUND J, D Sc, F.R S, F.C S 64 Twyford-avenue, West Acton, W
1908 §Mills, Miss Gertrude Isabel Nurney, Glenagarey, Co Dublin.
1908 §Mills, John Arthur, M B Durham County Asylum, Winterton, Ferryhill
1908. §Mills, W H, M Inst C E. Nurney, Glenagarey, Co Dublin.
1902 ‡Mills, W Sloan, M A Vine Cottage, Donaghmore, Newry
1907. ‡Milne, A, M A. University School, Hastings
1910 §Milne, J. B Cross Grove House, Totley, near Sheffield.
1910. *Milne, James Robert, D Sc., F.R S.E. 11 Melville-crescent, Edinburgh.
1882. *MILNE, JOHN, D Sc, F R S, F G.S Shide, Newport, Isle of Wight.
1903. *Milne, R M Royal Naval College, Dartmouth, South Devon
1898 *Milner, S Roslington, D Sc The University, Sheffield
1908 §Milroy, T H, M D, Dunville Professor of Physiology in Queen's College, Belfast
1907 §MILTON, J H, F G S, F L S, F R G S, 8 College-avenue, Crosby, Liverpool.
1912. §Minchin, E A, M A. F R S 53 Cheyne-court, Chelsea, S.W
1880. ‡MINCHIN, G M, M A, F R S 149 Banbury-road, Oxford.
1901. *Mitchell, Andrew Acworth 7 Huntly-gardens, Glasgow.
1901 *Mitchell, G A 5 West Regent-street, Glasgow.
1909. ‡Mitchell, J F. 211 Rupert-street, Winnipeg, Canada.
1885 ‡MITCHELL, P CHALMERS, M A, D Sc, F R S, Sec Z S (Pres D, 1912, Council, 1906–) Zoological Society, Regent's Park, N W.
1908. ‡Mitchell, W M. 2 St. Stephen's Green, Dublin.
1905. *Mitchell, W. E C Box 129, Johannesburg.
1895 *Moat, William, M A. Johnson Hall, Eccleshall, Staffordshire
1908 ‡Moffat, C. B 36 Hardwicke-street, Dublin
1905 ‡Moir, James, D Sc. Mines Department, Johannesburg
1905. §Molengraaff, Professor G A F Voorstraat 60, Delft, The Hague
1883 ‡Mollison, W. L, M A Clare College, Cambridge.
1900 *MONCKTON, H. W, Treas. L S, F G.S. 3 Harcourt-buildings, Temple, E C.
1905. *MONCRIEFF, Colonel Sir C SCOTT, G C S I, K.C M G., R.E (Pres. G, 1905) 11 Cheyne-walk, S W.
1905 ‡Moncrieff, Lady Scott 11 Cheyne-walk, S W.
1891. *Mond, Robert Ludwig, M A, F R S E, F G S 20 Avenue-road Regent's Park, N.W.
1909 ‡Moody, A. W., M.D. 432½ Main-street, Winnipeg, Canada.
1909 §MOODY, G. T., D.Sc. Lorne House, Dulwich, S.E.
1912. §Moore, Benjamin, D Sc, Professor of Bio-Chemistry in the University of Liverpool 84 Shrewsbury-road, Birkenhead.
1911. §Moore, E S., Professor of Geology and Mineralogy in the School of Mines, Pennsylvania State College, Pennsylvania, U.S A
1908. *Moore, Sir F. W. Royal Botanic Gardens, Glasnevin, Dublin.
1894 ‡Moore, Harold E Oaklands, The Avenue, Beckenham, Kent
1908 ‡Moore, Sir John W, M D 40 Fitzwilliam-square West, Dublin.

Year of Election

1901. *Moore, Robert T 142 St Vincent-street, Glasgow.
1905. ‡Moore, T H Thornhill Villa, Marsh, Huddersfield.
1892 ‡Moray, The Right Hon the Earl of, F.G S. Kinfauns Castle, Perth.
1912. §Moray, The Countess of Kinfauns Castle, Perth.
1896. *Mordey, W. M. 82 Victoria-street, S.W.
1901. *Moreno, Francisco P. Parana 915, Buenos Aires.
1905. *Morgan, Miss Annie. Friedrichstrasse No 2, Vienna.
1895. ‡MORGAN, C. LLOYD, F.R S, F G S, Professor of Psychology in the University of Bristol.
1902 ‡MORGAN, GILBERT T., D Sc, F I C, Professor of Chemistry in the Royal College of Science, Dublin
1902. *Morgan, Septimus Vaughan 37 Harrington-gardens, S.W.
1901. *Morison, James. Perth
1883 *MORLEY, HENRY FORSTER, M A, D Sc, F.C S 5 Lyndhurst-road, Hampstead, N W
1906. ‡Morrell, H. R Scarcroft-road, York.
1896. *Morrell, Dr R S. Tor Lodge, Tettenhall Wood, Wolverhampton.
1892 ‡MORRIS, Sir DANIEL, K C M G, D Sc, F L S. 14 Crabton-close, Boscombe, Hants
1908. ‡Morris, E A Montmorency, M A, M R I A Winton House, Cabra, Co Dublin
1896. *Morris, J T. 36 Cumberland-mansions, Seymour-place, W
1880. §Morris, James 23 Brynymor Cresent, Swansea
1907. ‡Morris, Colonel Sir W. G, K C M.G Care of Messrs Cox & Co, 16 Charing Cross, W C.
1899. *MORROW, JOHN, M Sc, D Eng Armstrong College, Newcastle-upon-Tyne
1909. ‡Morse, Morton F Wellington-crescent, Winnipeg, Canada.
1886 *Morton, P F. 15 Ashley-place, Westminster, S W.
1896 *MORTON, WILLIAM B, M A, Professor of Natural Philosophy in Queen's University, Belfast
1908 ‡Moss, Dr. C E Botany School, Cambridge
1912 §Moss, Mrs 154 Chesterton-road, Cambridge
1876 §Moss, RICHARD JACKSON, F I C, M R I A Royal Dublin Society, and St Aubyn's, Ballybrack, Co Dublin
1892. *Mostyn, S G, M A, M B Health Office, Houndgate, Darlington.
1912 §Moulton, J C Sarawak Museum, Sarawak
1878. *MOULTON, The Right Hon Lord Justice, M A, K C, F R S 57 Onslow-square, S W.
1899 §Mowll, Martyn Chaldercot, Leyburne-road, Dover
1905. ‡Moylan, Miss V C 3 Canning-place, Palace Gate, W
1905. *Moysey, Miss E L Pitcroft, Guildford, Surrey
1911. *Moysey, Lewis, B A, M B. St Moritz, Ilkeston-road, Nottingham
1912 §Mudie, Robert Francis 6 Fintry-place, Broughty Ferry
1902. §Muir, Arthur H 2 Wellington-place, Belfast
1907. *Muir, Professor James. 31 Burnbank-gardens, Glasgow.
1874 ‡MUIR, M. M PATTISON, M A Hillcrest, Farnham, Surrey
1909. ‡Muir, Robert R. Grain Exchange-building, Winnipeg, Canada.
1912 §Muir, Thomas Scott 3 Tantallon-place, Edinburgh.
1904 §Muir, William, I S O Rowallan, Newton Stewart, N B
1872. *MUIRHEAD, ALEXANDER, D Sc, F.R S, F C S. 12 Carteret-street, Queen Anne's Gate, Westminster, S.W.
1905. *Muirhead, James M. P, F R S.E Royal Automobile Club, Pall Mall, S W
1876. *Muirhead, Robert Franklin, B A., D.Sc 64 Great George-street, Hillhead, Glasgow.

Year of Election

1902. ‡Mullan, James Castlerock, Co Derry.
1884. *MULLER, HUGO, Ph D., F R S, F.C S. 13 Park-square East, Regent's Park, N W.
1908. ‡MULLIGAN, JOHN. (Local Sec 1908.) Greinan, Adelaide-road, Kingstown, Co. Dublin
1904. ‡Mullinger, J. Bass, M.A. 1 Bene't-place, Cambridge.
1911. ‡Mumby, Dr. B. H. Borough Asylum, Milton, Portsmouth.
1898. ‡Mumford, C. E. Cross Roads House, Bouverie-road, Folkestone.
1901. *Munby, Alan E. 44 Downshire-hill, Hampstead, N W.
1906. ‡Munby, Frederick J. Whixley, York
1904. ‡Munro, A. Queen's College, Cambridge
1909. ‡Munro, George. 188 Roslyn-road, Winnipeg, Canada.
1883. *MUNRO, ROBERT, M.A , M D , LL D. (Pres. H, 1893.) Elmbank, Largs, Ayrshire, N.B.
1909. ‡Munson, J. H., K.C. Wellington-crescent, Winnipeg, Canada.
1911 ‡Murdoch, W. H. F , B Sc. 14 Howitt-road, Hampstead, N.W
1909. §Murphy, A. J. Vanguard Manufacturing Co., Dorrington-street, Leeds.
1908. ‡Murphy, Leonard 156 Richmond-road, Dublin.
1908. ‡MURPHY, WILLIAM M , J P. Dartry, Dublin
1905 ‡Murray, Charles F K , M D. Kenilworth House, Kenilworth, Cape Colony
1905. §Murray, Sir James, LL D , Litt D. Sunnyside, Oxford.
1905 §Murray, Lady Sunnyside, Oxford
1884. ‡MURRAY, Sir JOHN, K C B , LL D , D Sc , Ph.D , F.R S , F R S E. (Pres. E, 1899) Challenger Lodge, Wardie, Edinburgh.
1903 §Murray, Colonel J D Rowbottom-square, Wigan.
1892. ‡Murray, T S , D Sc 27 Shamrock-street, Dundee.
1909. ‡Murray, W. C University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
1912 *Musgrove, James, M D , Professor of Anatomy in the University of St Andrews
1870 *Muspratt, Edward Knowles Seaforth Hall, near Liverpool
1906. ‡Myddelton-Gavey, E. H., M R C S., J.P. Stanton Prior, Meads, Eastbourne.
1902. ‡Myddleton, Alfred 62 Duncairn-street, Belfast
1902. *Myers, Charles S , M A , M D Great Shelford, Cambridge
1909. *Myers, Henry. The Long House, Leatherhead.
1906. ‡Myers, Jesse A Glengarth, Walker-road, Harrogate.
1890. *MYRES, JOHN L , M A , F S A. (Pres. H, 1909 ; Council, 1909-), Wykeham Professor of Ancient History in the University of Oxford. 101 Banbury-road, Oxford.

1886. ‡NAGEL, D H , M A. (Local Sec. 1894) Trinity College, Oxford.
1892. *Nairn, Sir Michael B , Bart. Kirkcaldy, N B.
1890. ‡Nalder, Francis Henry. 34 Queen-street, E C
1908 ‡Nally, T. H Temple Hill, Terenure, Co Dublin.
1872. ‡NARES, Admiral Sir G. S , K C B , R N., F.R S., F.R G S. 7 The Crescent, Surbiton
1909. ‡Neild, Frederic, M.D. Mount Pleasant House, Tunbridge Wells.
1883. *Neild, Theodore, M A. Grange Court, Leominster.
1898. *Nevill, Rev. J. H N., M.A. The Vicarage, Stoke Gabriel, South Devon.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.

Year of Election.

1889. ‡NEVILLE, F. H, M.A., F.R.S Sidney College, Cambridge.
1889. *NEWALL, H. FRANK, M.A, F R.S., F R.A S, Professor of Astrophysics in the University of Cambridge. Madingley Rise, Cambridge.
1912. §Newberry, Percy E, M.A., Professor of Egyptology in the University of Liverpool. The Grange, St Michael's Hamlet, Liverpool.
1901 ‡Newbigin, Miss Marion, D Sc Royal Scottish Geographical Society, Edinburgh
1901. ‡Newman, F. H. Tullie House, Carlisle
1889. ‡Newstead, A H L, B A 38 Green-street, Bethnal Green, N.E.
1912. *Newton, Arthur U. University College, W C
1892. ‡NEWTON, E. T., F.R.S, F.G S. Florence House, Willow Bridge-road, Canonbury, N
1908. ‡Nicholls, W. A. 11 Vernham-road, Plumstead, Kent.
1908. ‡Nichols, Albert Russell 30 Grosvenor-square, Rathmines, Co Dublin
1908 §Nicholson, J W, M A, D Sc Trinity College, Cambridge.
1887. ‡Nicholson, John Carr, J P. Moorfield House, Headingley, Leeds
1884. ‡NICHOLSON, JOSEPH S, M A, D Sc (Pres F, 1893), Professor of Political Economy in the University of Edinburgh
1911. ‡Nicol, J C, M A The Grammar School, Portsmouth
1908. ‡NIXON, Sir CHRISTOPHER, Bart, M D, LL D, D L 2 Merrion-square, Dublin
1863 *NOBLE, Sir ANDREW, Bart, K C B, D Sc, F R S, F R A S, F C S. (Pres. G, 1890; Council, 1903-06, Local Sec 1863) Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne
1863. §NORMAN, Rev Canon ALFRED MERLE, M A, D.C L, LL D, F R S, F.L S The Red House, Berkhamsted
1888. ‡Norman, George 12 Brock-street, Bath
1912. §Norrie, Robert University College, Dundee
1894 §NOTCUTT, S A, LL M, B A, B Sc (Local Sec 1895) Constitution-hill, Ipswich
1909. ‡Nugent, F. S 81 Notre Dame-avenue, Winnipeg, Canada.
1910. §Nunn, T Percy, M A, D Sc London Day Training College, Southampton-row, W C
1912 §Nuttall, W H Cooper Laboratory for Economic Research, Rickmansworth-road, Watford.
1908. ‡Nutting, Sir John, Bart St Helen's, Co Dublin.

1898. *O'Brien, Neville Forth Fryth, Pyrford, Surrey.
1908 ‡O'Carroll, Joseph, M D 43 Merrion-square East, Dublin
1883 ‡Odgers, William Blake, M A, LL D, K C 15 Old-square, Lincoln's Inn, W C
1910 *Odling, Marmaduke, B A, F G S 15 Norham-gardens, Oxford.
1858 *ODLING, WILLIAM, M B, F R S, V P C.S. (Pres. B, 1864; Council, 1865–70) 15 Norham-gardens, Oxford
1911. *O'DONOGHUE, CHARLES H, D Sc University College, Gower-street, W C.
1908. §O'Farrell, Thomas A., J P 30 Lansdowne-road, Dublin.
1902. ‡Ogden, James Neal Claremont, Heaton Chapel, Stockport
1876. ‡Ogilvie, Campbell P Lawford-place, Manningtree.
1885. ‡OGILVIE, F GRANT, C B, M A, B Sc, F R S E (Local Sec. 1892) Board of Education, S W.
1912. §Ogilvy, J W. 18 Bloomsbury-square, W C
1905. *Oke, Alfred William, B A, LL.M, F.G S., F L S. 32 Denmark-villas, Hove, Brighton.

Year of Election

1905. §Okell, Samuel, F.R.A.S. Overley, Langham-road, Bowdon Cheshire.
1908. §Oldham, Charles Hubert, B.A., B.L., Professor of Commerce in the National University of Ireland. 5 Victoria-terrace, Rathgar, Dublin.
1892. ‡OLDHAM, H. YULE, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1893. *OLDHAM, R. D., F.R.S., F.G.S. 8 North-street, Horsham, Sussex.
1912. §O'Leary, Rev. William, S.J. Mungret College, Limerick.
1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. ‡OLIVER, F. W., D.Sc., F.R.S., F.L.S. (Pres. K, 1906), Professor of Botany in University College, London, W.C.
1889. ‡Oliver, Professor Sir Thomas, M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §OLSEN, O. T., D.Sc., F.L.S., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1908. ‡O'Neill, Rev. G., M.A. University College, St. Stephen's Green, Dublin.
1902. ‡O'Neill, Henry, M.D. 6 College-square East, Belfast.
1905. ‡O'Reilly, Patrick Joseph. 7 North Earl-street, Dublin.
1884. *Orpen, Rev. T. H., M.A. Mark Ash, Abinger Common, Dorking.
1901. ‡Orr, Alexander Stewart. 10 Medows-street, Bombay, India.
1909. ‡Orr, John B. Crossacres, Woolton, Liverpool.
1908. *Orr, William. Dungarvan, Co. Waterford.
1904. *ORTON, K. J. P., M.A., Ph.D., Professor of Chemistry in University College, Bangor.
1910. §Osborn, T. G. B., M.Sc., Professor of Botany in the University of Adelaide, South Australia.
1901. ‡Osborne, W. A., D.Sc. University College, W.C.
1908. ‡O'Shaughnessy, T. L. 64 Fitzwilliam-square, Dublin.
1887. ‡O'Shea, L. T., B.Sc. University College, Sheffield.
1865. *Osler, Henry F. Coppy-hill, Linthurst, near Bromsgrove, Birmingham.
1884. ‡OSLER, Sir WILLIAM, Bart., M.D., LL.D., F.R.S., Regius Professor of Medicine in the University of Oxford. 13 Norham-gardens, Oxford.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1896. ‡Oulton, W. Hillside, Gateacre, Liverpool.
1906. ‡Owen, Rev. E. C. St. Peter's School, York.
1903. *Owen, Edwin, M.A. Terra Nova School, Birkdale, Lancashire.
1896. ‡Owen, Peter. The Elms, Capenhurst, Chester.
1911. §Owens, J. S., M.D., Assoc. M. Inst. C.E. 47 Victoria-street, S.W.
1910. *Oxley, A. E. Rose Hill View, Kimberworth-road, Rotherham.

1909. ‡Pace, F. W. 388 Wellington-crescent, Winnipeg, Canada.
1908. ‡Pack-Beresford, Denis, M.R.I.A. Fenagh House, Bagenalstown, Ireland.
1906. §Page, Carl D. Wyoming House, Aylesbury, Bucks.
1903. *Page, Miss Ellen Iva. Turret House, Felpham, Sussex.
1883. ‡Page, G. W. Bank House, Fakenham.
1911. §Paget, Stephen, M.A., F.R.C.S. 21 Ladbroke-square, W.
1912. §Pahic, Paul. 52 Albert Court, Kensington Gore, S.W.
1911. §Paine, H. Howard. 50 Stow-hill, Newport, Monmouthshire.

Year of Election

1870 *PALGRAVE, Sir ROBERT HARRY INGLIS, F.R.S., F.S.S. (Pres. F 1883.) Henstead Hall, Wrentham, Suffolk.
1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1878 *Palmer, Joseph Edward. Royal Societies Club, St. James's-street, S.W.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1880. *Parke, George Henry, F.L.S., F.G.S. Care of W. T. Cooper, Esq., Aysgarth, The Mall, Southgate, N.
1904. ‡PARKER, E. H., M.A. Thorneycreek, Herschel-road, Cambridge.
1909. §PARKER, M. A., B.Sc., F.C.S. (Local Sec. 1909), Professor of Chemistry in the University of Manitoba, Winnipeg, Canada.
1891. ‡PARKER, WILLIAM NEWTON, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1905. *Parkes, Tom E. P.O. Box 4580, Johannesburg.
1899. *Parkin, John. Blaithwaite, Carlisle.
1905. *Parkin, Thomas. Blaithwaite, Carlisle.
1906. §Parkin, Thomas, M.A., F.L.S., F.Z.S., F.R.G.S. Fairseat, High Wickham, Hastings.
1879. *Parkin, William. The Mount, Sheffield.
1911. ‡Parks, Dr. G. J. 18 Cavendish-road, Southsea.
1903. §Parry, Joseph, M.Inst.C.E. Woodbury, Waterloo, near Liverpool.
1908. ‡Parry, W. K., M.Inst.C.E. 6 Charlemont-terrace, Kingstown, Dublin.
1878. ‡PARSONS, Hon. Sir C. A., K.C.B., M.A., Sc.D., F.R.S., M.Inst.C.E. (Pres. G, 1904.) Holeyn Hall, Wylam-on-Tyne.
1904. ‡Parsons, Professor F. G. St. Thomas's Hospital, S.E.
1905. *Parsons, Hon. Geoffrey L. Northern Counties Club, Newcastle-on-Tyne.
1898. *Partridge, Miss Josephine M. 15 Grosvenor-crescent, S.W.
1887. ‡PATERSON, A. M., M.D., Professor of Anatomy in the University of Liverpool.
1908. ‡Paterson, M., LL.D. 7 Halton-place, Edinburgh.
1909. ‡Paterson, William. Ottawa, Canada.
1897. ‡Paton, D. Noël, M.D. Physiological Laboratory, The University, Glasgow.
1883. *Paton, Rev. Henry, M.A. Airtnoch, 184 Mayfield-road, Edinburgh.
1884. *Paton, Hugh. Box 2400, Montreal, Canada.
1908. §PATTEN, C. J., M.A., M.D., Sc.D., Professor of Anatomy in the University of Sheffield.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
1883. ‡Paul, George. 32 Harlow Moor-drive, Harrogate.
1887. *Paxman, James. Standard Iron Works, Colchester.
1912. *Payne, Miss Edith. Care of Mrs. Roberts, Lothian, St. Marychurch, Torquay.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1881. ‡Payne, Mrs. 4 Ulsterville-avenue, Belfast.
1888. *Paynter, J. B. Hendford Manor, Yeovil.
1876. ‡Peace, G. H., M.Inst.C.E. Monton Grange, Eccles, near Manchester.
1906. ‡Peace, Miss Gertrude. 39 Westbourne-road, Sheffield.
1885. ‡PEACH, B. N., LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1912.) Geological Survey Office, George-square, Edinburgh.
1911. §Peake, Harold J. E. Westbrook House, Newbury.
1886. *Pearce, Mrs. Horace. Collingwood, Manby-road, West Malvern.
1883. ‡Pearson, Arthur A., C.M.G. Hillsborough, Heath-road, Petersfield, Hampshire.

Year of Election

1893. *Pearson, Charles E. Hillcrest, Lowdham, Nottinghamshire.
1898. ‡Pearson, George. Bank-chambers, Baldwin-street, Bristol
1905. §Pearson, Professor H. H W, M.A., F.L.S. South African College, Cape Town.
1883. ‡Pearson, Miss Helen E. Oakhurst, Birkdale, Southport.
1906. ‡Pearson, Dr Joseph The Museum, Colombo, Ceylon.
1904. ‡Pearson, Karl, M A, F R S, Professor of Eugenics in the University of London 7 Well-road, Hampstead, N.W
1909. ‡Pearson, William. Wellington-crescent, Winnipeg, Canada.
Peckitt, Henry Carlton Husthwaite, Thirsk, Yorkshire.
1855. *PECKOVER, Lord, LL D, F S A, F L S, F R G S Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire
1885. ‡Peddie, William, Ph D, F R S E, Professor of Natural Philosophy in University College, Dundee
1884 ‡Peebles, W. E 9 North Frederick-street, Dublin.
1878 *Peek, William. 4 Carlyle-mansions, Brunswick-place, Hove.
1901 *Peel, Right Hon Viscount. 13 King's Bench-walk, Temple, E C.
1905. §Peirson, J. Waldie. P O Box 561, Johannesburg
1905. ‡Pemberton, Gustavus M. P O Box 93, Johannesburg.
1887. ‡PENDLEBURY, WILLIAM H, M A, F C S (Local Sec. 1899) Woodford House, Mountfields, Shrewsbury.
1894. ‡Pengelly, Miss Lamorna, Torquay.
1896. ‡Pennant, P P Nantlys, St Asaph
1898. ‡Percival, Francis W, M A, F R G S. 1 Chesham-street, S.W.
1908. ‡Percival, Professor John, M A University College, Reading.
1905. ‡Péringuey, L, D Sc, F Z S. South African Museum, Cape Town
1894. ‡PERKIN, A. G, F R S, F R S E, F C S, F I C. 8 Montpelier-terrace, Hyde Park, Leeds
1902. *Perkin, F. Mollwo, Ph D The Firs, Hengrave-road, Honor Oak Park, S E
1884. ‡PERKIN, WILLIAM HENRY, LL.D Ph D., F R.S, F.R S.E. (Pres. B. 1900, Council, 1901–07), Waynflete Professor of Chemistry in the University of Oxford. The Museums, Oxford.
1864. *Perkins, V R Wotton-under-Edge, Gloucestershire.
1898 *Perman, E P, D Sc. University College, Cardiff.
1909. ‡Perry, Rev. Professor E. Guthrie. 246 Kennedy-street, Winnipeg, Canada.
1874. *PERRY, JOHN, M E, D Sc, LL D, F R S. (GENERAL TREASURER, 1904– ; Pres. G, 1902; Council, 1901–04), Professor of Mechanics and Mathematics in the Imperial College of Science and Technology, S W 14A Campden Hill Court, W.
1904. *Pertz, Miss D. F. M. 2 Cranmer-road, Cambridge
1900. *PETAVEL, J. E, M Sc, F R S, Professor of Engineering in the University of Manchester.
1901. ‡Pethybridge, G. H., Ph.D Royal College of Science, Dublin.
1910. *Petrescu, Captain Dimitrie, R.A, M.Eng Scoala Superiora de Messern, Bucharest, Rumania.
1895. ‡PETRIE, W M FLINDERS, D C L, F R S (Pres H, 1895), Professor of Egyptology in University College, W C.
1871. *Peyton, John E. H., F R.A S., F G S. Vale House, St. Helier's, Jersey.
1911. ‡Philip, Alexander. Union Bank Buildings, Brechin.
1903. ‡Philip, James C. 20 Westfield-terrace, Aberdeen.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.

Year of Election

1877. §Philips, T. Wishart Elizabeth Lodge, Crescent-road, South Woodford, Essex
1905 ‡Phillimore, Miss C M Shiplake House, Henley-on-Thames.
1899. *Phillips, Charles E. S, F R S E Castle House, Shooter's Hill, Kent
1910 *Phillips, P P, Ph.D, Professor of Chemistry in the Thomason Engineering College, Rurki, United Provinces, India.
1890 ‡Phillips, R W, M A, D Sc, F L S, Professor of Botany in University College, Bangor 2 Snowdon-villas, Bangor.
1909. *Phillips, Richard 15 Dogpole, Shrewsbury.
1883 *Pickard, Joseph William Oatlands, Lancaster
1901 §Pickard, Robert H, D Sc Billinge View, Blackburn
1885 *Pickering, Spencer P U, M A, F R S Harpenden, Herts.
1884 *Pickett, Thomas E, M D Maysville, Mason Co, Kentucky, U S A.
1907 ‡Pickles, A R, M A Todmorden-road, Burnley
1888 *Pidgeon, W R Lynsted Lodge, St Edmund's-terrace, Regent's Park, N W.
1865 ‡Pike, L Owen 10 Chester-terrace, Regent's Park, N W.
1896 *Pilkington, A C Rocklands, Rainhill, Lancashire
1905 ‡Pilling, Arnold Royal Observatory, Cape Town
1896 *Pilling, William Rosario, Heene-road, West Worthing
1905 ‡Pim, Miss Gertrude Charleville, Blackrock, Co Dublin
1911 ‡Pink, H R The Mount, Fareham, Hants
1911 ‡Pink, Mrs H R The Mount, Fareham, Hants
1911 ‡Pink, Mrs J E The Homestead, Eastern-parade, Southsea
1908 *Pio, Professor D A 14 Leverton-street, Kentish Town, N W
1908 ‡Pirrie, The Right Hon Lord, LL D, M Inst C E Downshire House, Belgrave-square, S W
1909. ‡Pitblado, Isaac, K C. 91 Balmoral-place, Winnipeg, Canada.
1893 *Pitt, Walter, M Inst C E 3 Lansdown grove, Bath
1908 §Pixell, Miss Helen L M St Faith's Vicarage, Stoke Newington, N
1900 *Platts, Walter Morningside, Scarborough.
1911. *Plimmer, R H A 3 Hall-road, N W
1898 ‡Plummer, W E, M A, F R A S The Observatory, Bidston, Birkenhead
1908 ‡Plunkett, Count G N National Museum of Science and Art, Dublin
1908 ‡Plunkett, Colonel G T, C B Belvedere Lodge, Wimbledon, S W.
1907. *Plunkett, Right Hon Sir Horace, K C V O, M A, F R S. Kilteragh, Foxrock, Co Dublin
1900. *Pocklington, H Cabourn, M A, D Sc, F R S. 11 Regent Park-terrace, Leeds
1904 ‡Pollard, William 12 Aberdare-gardens, South Hampstead, N W.
1908. ‡Pollok, James H., D Sc. 6 St James's-terrace, Clonshea, Dublin.
1906. *Pontifex, Miss Catherine E. 7 Hurlingham-court, Fulham, S W.
1911 §Poore, Major-General F H 1 St Helen's-parade, Southsea.
1907. §Pope, Alfred, F S A South Court, Dorchester.
1900. *Pope, W. J, M A, LL D., F R S, Professor of Chemistry in the University of Cambridge
1892. ‡Popplewell, W C, M Sc, Assoc.M Inst C E Bowden-lane, Marple, Cheshire.
1901. §Porter, Alfred W, B Sc, F R S. 87 Parliament Hill-mansions, Lissenden-gardens, N W.
1883. *Porter, Rev C. T, LL D, D D All Saints' Vicarage, Southport.
1905. §Porter, J. B, D Sc, M Inst C E, Professor of Mining Engineering in the McGill University, Montreal, Canada

Year of Election

1905. ‡Porter, Mrs. McGill University, Montreal, Canada.
1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the Armstrong College, Newcastle-upon-Tyne. 13 Highbury, Newcastle-upon-Tyne.
1906. ‡Potter-Kirby, Alderman George. Clifton Lawn, York.
1907. ‡Potts, F. A. University Museum of Zoology, Cambridge.
1908. *Potts, George, Ph.D., M.Sc. Grey University College, Bloemfontein, South Africa.
1886. *Poulton, Edward B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S. (Pres. D, 1896; Council, 1895–1901, 1905–12), Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Mrs. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer, M.A. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Miss. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Miss M. Wykeham House, Banbury-road, Oxford.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole-street, Cavendish-square, W.
1887. §Pownall, George H. 20 Birchin-lane, E.C.
1883. ‡Poynting, J. H., D.Sc., F.R.S. (Pres. A, 1899), Professor of Physics in the University of Birmingham. 10 Ampton-road, Edgbaston, Birmingham.
1908. ‡Praeger, R. Lloyd, B.A., M.R.I.A. Lisnamae, Rathgar, Dublin.
1907. *Prain, Lieut.-Col. Sir David, C.I.E., C.M.G., M.B., F.R.S. (Pres. K, 1909; Council, 1907–) Royal Gardens, Kew.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1906. ‡Pratt, Miss Edith M., D.Sc. The Woodlands, Silverdale, Lancashire.
1869. *Preece, Sir William Henry, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1888; Council, 1888–95, 1896–1902.) Gothic Lodge, Wimbledon Common, S.W.
1888. *Preece, W. Llewellyn, M.Inst.C.E. 8 Queen Anne's-gate, S.W.
1904. §Prentice, Mrs. Manning. Thelema, Undercliff-road, Felixstowe.
1892. ‡Prentice, Thomas. Willow Park, Greenock.
1910. ‡Prescott, R. M. (Local Sec., 1910.) Town Hall, Sheffield.
1906. ‡Pressly, D. L. Coney-street, York.
1889. ‡Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1903. §Price, Edward E. Oaklands, Oaklands-road, Bromley, Kent.
1888. ‡Price, L. L. F. R., M.A., F.S.S. (Pres. F, 1895; Council, 1898–1904.) Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1897. *Price, W. A., M.A. 135 Sandyford-road, Newcastle-on-Tyne.
1908. §Priestley, J. H., B.Sc., Professor of Botany in the University of Leeds.
1909. *Prince, Professor E. E., LL.D. 206 O'Connor-street, Ottawa, Canada.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 70 Fairhazel-gardens, South Hampstead, N.W.
1876. *Pritchard, Urban, M.D., F.R.C.S. 26 Wimpole-street, W.
1881. §Procter, John William. Ashcroft, York.
1884. *Proudfoot, Alexander, M.D. Care of E. C. S. Scholefield, Esq., Provincial Librarian, Victoria, B.C., Canada.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1903. ‡Pullen-Burry, Miss. Lyceum Club, 128 Piccadilly, W.

Year of Election

1904 ‡Punnett, R C, M A, F R S Professor of Biology in the University of Cambridge Caius College, Cambridge
1885. ‡PURDIE, THOMAS, B Sc, Ph D, F R S, Professor of Chemistry in the University of St Andrews 14 South-street, St Andrews, N B
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M A, Dean of York The Deanery, York.
1884 *Purves, W Laidlaw 20 Stratford-place, Oxford-street, W.
1911 ‡Purvis, J E Corpus Christi College, Oxford
1912 §Pycraft, Dr W. P. British Museum (Natural History), Cromwell-road, S W.
1898 *Pye, Miss E St Mary's Hall, Rochester
1883 §Pye-Smith, Arnold 32 Queen Victoria-street, E C
1883 ‡Pye-Smith, Mrs 32 Queen Victoria-street, E C
1868 ‡PYE-SMITH, P H, M D, F R S 48 Brook-street, W; and Guy's Hospital, S E
1879 ‡Pye-Smith, R J 450 Glossop-road, Sheffield
1911 ‡Pye-Smith, Mrs R J 450 Glossop-road, Sheffield

1893 ‡Quick, James 22 Bouverie-road West, Folkestone
1906 *Quiggin, Mrs A Hingston 88 Hartington-grove, Cambridge.

1879. ‡Radford, R Heber 15 St James's-row, Sheffield
1912 §Radok, F 12 Central-hill, Upper Norwood, S E
1855 *Radstock, The Right Hon Lord Mayfield, Woolston, Southampton
1911 §Rae, John T National Temperance League, Paternoster House, Paternoster-row, E C
1887 *Ragdale, John Rowland The Beeches, Stand, near Manchester
1898 *Raisin, Miss Catherine A, D Sc, Bedford College, York-place, Baker-street, W
1896 *RAMAGE, HUGH, M A The Technical Institute, Norwich
1894 *RAMBAUT, ARTHUR A, M A, D Sc, F R S, F R A S, M R I A Radcliffe Observatory, Oxford
1908 ‡Rambaut, Mrs Radcliffe Observatory, Oxford
1912 §Ramsay, Colonel R. G Wardlaw Whitehill, Rosewell, Midlothian.
1876 *RAMSAY, Sir WILLIAM, K C B, Ph D, D Sc, F R S (PRESIDENT, 1911; Pres B, 1897, Council 1891–98) 19 Chester-terrace, Regent's Park, N W
1883 ‡Ramsay, Lady 19 Chester-terrace, Regent's Park, N W.
1869 *Rance, H W. Henniker, LL D 10 Castletown-road, W
1907 ‡Rankine, A O 21 Drayton-road, West Ealing, W
1868 *Ransom, Edwin, F R G S 24 Ashburnham-road, Bedford.
1861 ‡RANSOME, ARTHUR, M A, M D, F R S (Local Sec 1861) Sunnyhurst, Dean Park, Bournemouth
1903 ‡Rastall, R H Christ's College, Cambridge
1892. *Rathbone, Miss May Backwood, Neston, Cheshire
1874 ‡RAVENSTEIN, E G, F R G S, F S S (Pres E, 1891) 2 York-mansions, Battersea Park, S W.
1913 §Raw, Frank, B Sc, F.G S The University, Edmund-street, Birmingham.
1908 *Raworth, Alexander St John's Manor, Jersey
1905 ‡Rawson, Colonel Herbert E, R E Army Headquarters, Pretoria

Year of Election

1868. *RAYLEIGH, The Right Hon. Lord, O M., M A., D C.L, LL D., F R S, F R A S, F R G S. (PRESIDENT, 1884; TRUSTEE, 1883– ; Pres. A, 1882; Council, 1878-83), Professor of Natural Philosophy in the Royal Institution, London Terling Place, Witham, Essex

1883 *Rayne, Charles A. M D, M R C S St Mary's Gate, Lancaster.

1912. §Rayner, Miss M C. University College, Reading.

1897. *Rayner, Edwin Hartree, M A 40 Gloucester-road, Teddington, Middlesex

1907. ‡Rea, Carleton, B C L 34 Foregate-street, Worcester

1896 *READ, Sir CHARLES H, LL D, F S A. (Pres H, 1899) British Museum, W C

1902 ‡Reade, R. H. Wilmount, Dunmurry

1884 §Readman, J B, D Sc, F R S E Belmont, Hereford.

1890 *Redwood, Sir Boverton, Bart, D Sc, F R S E. F C S Wadham Lodge Wadham-gardens, N W

1908 ‡Reed, Sir Andrew, K C B, C V O, LL D. 23 Fitzwilliam-square, Dublin

1905 §Reed, J Howard, F R G S 16 St Mary's Parsonage, Manchester

1891 *Reed, Thomas A Bute Docks, Cardiff

1894 *Rees, Edmund S G Dunscar, Oaken, near Wolverhampton

1903 §Reeves, E A, F R G S Hillside, Reigate-road, Reigate

1911 §REEVES, Hon W PEMBER (Pres F 1911) London School of Economics, Clare Market, W C

1906 *Reichel, Sir H R, LL D, Principal of University College, Bangor Penrallt, Bangor, North Wales

1910 *Reid, Alfred, M B, M R C S Taiping, Perak, F M S

1901 *Reid, Andrew T 10 Woodside-terrace, Glasgow.

1904 ‡Reid, Arthur H 30 Welbeck-street, W

1881 §Reid, Arthur S, M A, F G S Trinity College, Glenalmond, N B

1883 *REID, CLEMENT, F R S, F L S, F G S One Acre, Milford-on-Sea, Hants.

1903 *Reid, Mrs E M, B Sc One Acre, Milford-on-Sea, Hants.

1892 ‡REID, E WAYMOUTH, B A, M B, F R S, Professor of Physiology in University College, Dundee

1908 ‡REID, GEORGE ARCHDALL, M B, C M, F R S E 9 Victoria-road South, Southsea

1901 *Reid, Hugh Belmont, Springburn, Glasgow

1901 ‡Reid, John 7 Park-terrace, Glasgow

1909. ‡Reid, John Young. 329 Wellington-crescent, Winnipeg, Canada.

1904 ‡Reid, P J Moor Cottage, Nunthorpe, R S O, Yorkshire

1912. §Reid, Professor R. W, M D 37 Albyn-place, Aberdeen

1897. ‡Reid, T Whitehead, M D St George's House, Canterbury.

1892. ‡Reid, Thomas Municipal Technical School, Birmingham.

1887. *Reid, Walter Francis Fieldside, Addlestone, Surrey

1912 §Reinheimer, Hermann. 43 King Charles-road, Surbiton

1875. ‡REINOLD, A W, C B, M A, F R.S (Council, 1890-95). 9 Vanbrugh Park-road, Blackheath, S E.

1894. ‡Rendall, Rev G H, M A, Litt D Charterhouse, Godalming

1891 *Rendell, Rev James Robson, B A Whinside, Whalley-road, Accrington

1903 *RENDLE, Dr. A B, M A., F.R S, F.L S 28 Holmbush-road, Putney, S W.

1889. *Rennie, George B. 20 Lowndes-street, S.W.

1906. ‡Rennie, John, D Sc. Natural History Department, University of Aberdeen.

Year of Election

1905 *Renton, James Hall Rowfold Grange, Billingshurst, Sussex.
1912 §Rettie, Theodore 10 Doune-terrace, Edinburgh
1904. ‡REUNERT, THEODORE, M Inst C E P.O Box 92, Johannesburg.
1912 §Rew, R. H, C B Board of Agriculture and Fisheries, 3 St. James's-square, S W
1905. §Reyersbach, Louis Care of Messrs. Wernher, Beit, & Co., 1 London Wall-buildings, E C.
1883. *Reynolds, A H 271 Lord-street, Southport
1871 ‡REYNOLDS, JAMES EMERSON, M D, D Sc, F R S, F C.S, M R I.A (Pres B, 1893; Council, 1893-99) 3 Inverness-gardens, W
1900 *Reynolds, Miss K M 8 Darnley-road, Notting Hill, W
1906 ‡Reynolds, S H., M A, Professor of Geology and Zoology in the University of Bristol
1907. §Reynolds, W Birstall Holt, near Leicester.
1899 *RHYS, The Right Hon Professor Sir JOHN, D Sc. (Pres H, 1900) Jesus College, Oxford
1877 *Riccardi, Dr Paul, Secretary of the Society of Naturalists. Riva Muro 14, Modena, Italy
1905 §Rich, Miss Florence, M A Granville School, Granville-road, Leicester
1906 ‡Richards, Rev A W. 12 Bootham-terrace, York
1869 *Richardson, Charles 3 Cholmley-villas, Long Ditton, Surrey
1912 §Richardson, Harry, M Inst E E Electricity Supply Department, Dudhope Crescent-road, Dundee
1889 ‡Richardson, Hugh, M A 12 St Mary's, York
1884 *Richardson, J Clarke Derwen Fawr, Swansea
1896 *Richardson, Nelson Moore, B A, F E S Montevideo, Chickerell, near Weymouth
1901 *Richardson, Professor Owen Willans. 105 Fitzrandolph-road, Princetown, N J, U S A
1876 §Richardson, William Haden City Glass Works, Glasgow
1883 *RIDEAL, SAMUEL, D Sc, F C S 28 Victoria-street, S W
1911 §Ridgeway, Miss A R 83 The Broadway, Watford
1902 §RIDGEWAY, WILLIAM, M A, D Litt, F B A (Pres H, 1908), Professor of Archæology in the University of Cambridge Flendyshe, Fen Ditton, Cambridge
1894 ‡RIDLEY, E P, F G S (Local Sec 1895) Burwood, Westerfield-road, Ipswich
1881 *Rigg, Arthur 150 Blomfield-terrace, W
1883 *RIGG, EDWARD, C.B, I S O, M A Royal Mint, E
1892 ‡Rintoul, D, M A Clifton College, Bristol
1912 §Rintoul, Miss L J Lahill, Largo, Fife
1910. ‡Ripper, William, Professor of Engineering in the University of Sheffield.
1903. *RIVERS, W. H R, M D, F.R S (Pres H, 1911) St John's College, Cambridge
1908. *Roaf, Herbert E, M D, D Sc 44 Rotherwick-road, Hendon, N.W
1898 *Robb, Alfred A Lisnabreeny House, Belfast
1902 *Roberts, Bruno 30 St George's-square, Regent's Park, N W
1887. *Roberts, Evan. 30 St George's-square, Regent's Park, N W
1896. ‡Roberts, Thomas J Ingleside, Park-road, Huyton, near Liverpool
1897. §ROBERTSON, Sir GEORGE S, K C S I. (Pres E, 1900) 1 Pump-court, Temple, E C
1897. ‡Robertson, Professor J W, C M G, LL D The Macdonald College, St Anne de Bellevue, Quebec, Canada

Year of Election

1912. §Robertson, R. A., M.A , B Sc., F.R.S.E., Lecturer on Botany in the University of St. Andrews.
1901. *Robertson, Robert, B Sc , M Inst.C.E 154 West George-street, Glasgow.
1909. ‡Robinson, E. M. 381 Main-street, Winnipeg, Canada.
1910. §Robinson, Lady E Maude The Manor, Worksop.
1903. ‡Robinson, G H. 1 Weld-road, Southport.
1905 ‡Robinson, Harry Duncan's-chambers, Shortmarket-street, Cape Town.
1902 ‡Robinson, Herbert C. Holmfield, Aigburth, Liverpool
1906. ‡*Robinson, H H , M A , F I C 75 Finborough-road, S W.*
1911 ‡Robinson, J. J 'West Sussex Gazette' Office, Arundel
1902 ‡Robinson, James, M A , F R G S Dulwich College, Dulwich, S E
1912. §Robinson, James North-terrace, Seghill, Northumberland
1888. ‡Robinson, John, M Inst C E 8 Vicarage-terrace, Kendal
1908 *Robinson, John Gorges, B A Cragdale, Settle, Yorkshire.
1910. ‡Robinson, John Hargreaves. Cable Ship 'Norseman,' Western Telegraph Co., Caixa no Correu No 117, Pernambuco, Brazil.
1895 *Robinson, Joseph Johnson 8 Trafalgar-road, Birkdale, Southport
1899. *Robinson, Mark, M Inst C E. Parliament-chambers, Westminster, S W.
1875. *Robinson, Robert, M Inst C E Beechwood, Darlington.
1908 ‡Robinson, Robert Field House, Chesterfield.
1904 ‡Robinson, Theodore R 25 Campden Hill-gardens, W
1909. ‡Robinson, Captain W 264 Roslyn-road, Winnipeg, Canada
1909. ‡Robinson, Mrs. W. 264 Roslyn-road, Winnipeg, Canada.
1904 ‡Robinson, W. H Kendrick House, Victoria-road, Penarth
1870 *Robson, E R Palace Chambers, 9 Bridge-street, Westminster, S W
1906 ‡Robson, J Nalton The Villa, Hull-road, York
1912. §Robson, W G 50 Farrington-street, Dundee
1872 *Robson, William 12 Albert-terrace, Edinburgh
1896 ‡Rodger, A M Natural History Museum, Perth
1885 *Rodger, Edward 1 Clairmont-gardens, Glasgow
1885 *Rodriguez, Epifanio New Adelphi Chambers, 6 Robert-street, Adelphi, W C
1905 ‡Roebuck, William Denison, F L S 259 Hyde Park-road, Leeds
1907 ‡*Roechling, H Alfred, M Inst C E 39 Victoria-street, S W*
1908 §Rogers, A G L Board of Agriculture and Fisheries, 8 Whitehall-place, S W
1898 ‡ROGERS, BERTRAM, M D. (Local Sec 1898) 11 York-place, Clifton, Bristol
1913. §Rogers, F , D Eng , B A , M Sc Rowardennan, Chelsea-road, Sheffield
1907. ‡Rogers, John D 85 St. George's-square, S W.
1890. *Rogers, L J , M A , Professor of Mathematics in the University of Leeds 15 Regent Park-avenue, Leeds
1906. ‡Rogers, Reginald A P Trinity College, Dublin
1909. ‡Rogers, Hon Robert. Roslyn-road, Winnipeg, Canada.
1884 *Rogers, Walter Lamorva, Falmouth.
1876. ‡ROLLIT, Sir A K , B A , LL D , D C L , F R.A S , Hon Fellow K.C L. 45 Belgrave-square, S.W.
1855. *ROSCOE, The Right Hon. Sir HENRY ENFIELD, B A , Ph D , LL D , D.C L , F.R S (PRESIDENT, 1887 ; Pres B, 1870, 1884 ; Council, 1874 -81 ; Local Sec 1861) 10 Bramham-gardens, S.W.
1905. ‡Rose, Miss G Mabel Ashley Lodge, Oxford
1883. *Rose, J. Holland, Litt.D Ethandune, Parkside-gardens, Wimbledon, S.W.

Year of Election

1894. *ROSE, T. K, D Sc, Chemist and Assayer to the Royal Mint. 6 Royal Mint, E.
1905. *Rosedale, Rev. H. G, D.D., F.S.A. 7 Gloucester-street, S.W.
1905. *Rosedale, Rev. W. E., D.D. St. Mary Bolton's Vicarage, South Kensington, S W.
1900. ‡Rosenhain, Walter, B A. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1909. ‡Ross, D. A. 116 Wellington-crescent, Winnipeg, Canada.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1908. ‡Ross, Sir John, of Bladensburg, K.C B. Rostrevor House, Rostrevor, Co Down.
1912. §Ross, Miss Joan M. Hazelwood, Warlingham, Surrey.
1902. ‡Ross, John Callender 46 Holland-street, Campden-hill, W.
1901. ‡Ross, Colonel Sir RONALD, K C B., F.R S, Professor of Tropical Medicine and Parasitology in the University of Liverpool. The University, Liverpool
1891. *Roth, H. Ling. Briarfield, Shibden, Halifax, Yorkshire.
1911. *Rothschild, Hon L. Walter, M P., D.Sc., Ph.D., F R S. Tring Park, Tring.
1901. *Rottenburg, Paul, LL D. Care of Messrs. Leister, Bock, & Co., Glasgow.
1899. *Round, J. C, M R C S 19 Crescent-road, Sydenham Hill, S E
1909. ‡Rounthwaite, C. H. E. Engineer's Office, Grand Trunk Pacific Railway of Canada, Winnipeg.
1884. *Rouse, M L, B A 47 Berlin-road, Catford, S E
1905 §Rousselet, Charles F Fir Island, Bittacy Hill, Mill Hill, N W.
1901 ‡Rowallan, the Right Hon Lord. Thornliebank House, Glasgow.
1903 *Rowe, Arthur W, M B, F G S Shottendane, Margate
1890. ‡Rowley, Walter, M Inst C E, F S A Alderhill, Meanwood, Leeds.
1881. *Rowntree, Joseph 38 St Mary's, York
1910. §Rowse, Arthur A, B.A, B Sc. Engineering Laboratory, Cambridge.
1875. *RÜCKER, Sir ARTHUR W, M A, D Sc, F R S (PRESIDENT, 1901; TRUSTEE, 1898- ; GENERAL TREASURER, 1891-98, Pres A, 1894, Council, 1888-91) Everington House, Newbury, Berkshire.
1869. §RUDLER, F. W, I S O., F.G S. Ethel Villa, Tatsfield, Westerham.
1901 *Rudorf, C C. G., Ph D, B Sc. Ivor, Cranley-gardens, Muswell Hill, N
1905. *Ruffer, Marc Armand, C M G, M A, M.D., B Sc. Quarantine International Board, Alexandria
1905 ‡Ruffer, Mrs. Alexandria
1904. ‡Ruhemann, Dr. S. 3 Selwyn-gardens, Cambridge
1909. ‡Rumball, Rev. M. C., B.A. Morden, Manitoba, Canada.
1896 *Rundell, T. W, F R Met Soc 3 Fenwick-street, Liverpool.
1911. ‡Rundle, Henry, F.R C S 13 Clarence-parade, Southsea
1912. *Rusk, Robert R., M.A, Ph D 4 Bains-crescent, Ayr.
1904. ‡Russell, E J, D Sc Rothamsted Experimental Station, Harpenden, Herts
1875. *Russell, The Hon F A. R Steep, Petersfield.
Russell, John 39 Mountjoy-square, Dublin
1883. *Russell, J. W. 28 Staverton-road, Oxford
1852. *Russell, Norman Scott Arts Club, Dover-street, W.
1908 ‡Russell, Robert. Arduagremia, Haddon-road, Dublin
1908 ‡RUSSELL, Right Hon T W, M P Olney, Terenure, Co Dublin.
1886. ‡Rust, Arthur Eversleigh, Leicester.
1909. *Rutherford, Hon. Alexander Cameron. Strathcona, Alberta, Canada.

Year of Election

1907. §RUTHERFORD, ERNEST, M A., D.Sc , F.R S (Pres. A, 1909), Professor of Physics in the University of Manchester.
1909. ‡Ruttan, Colonel H. N. Armstrong's Point, Winnipeg, Canada.
1908 ‡Ryan, Hugh, D Sc Omdurman, Orwell Park, Rathgar, Dublin.
1905. ‡Ryan, Pierce. Rosebank House, Rosebank, Cape Town
1909. ‡Ryan, Thomas. Assiniboine-avenue, Winnipeg, Canada.
1906. *RYMER, Sir JOSEPH SYKES The Mount, York

1903. ‡SADLER, M. E., C B , LL D (Pres L, 1906), Professor of Education in the Victoria University, Manchester. Eastwood, Weybridge
1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport
1871. ‡Sadler, Samuel Champernowne Church House, Westminster, S.W.
1903. ‡Sagar, J. The Poplars, Savile Park, Halifax
1873 *Salomons, Sir David, Bart , F G S. Broomhill, Tunbridge Wells.
1904 ‡SALTER, A E , D Sc , F G S 5 Clifton-place, Brighton
1911. §Sampson, R A , M A , F R S , Astronomer Royal for Scotland Royal Observatory, Edinburgh
1901. ‡Samuel, John S , J P , F R.S E City Chambers, Glasgow
1907. *Sand, Dr. Henry J S University College, Nottingham
1907. ‡Sandars, Miss Cora B Parkholme, Elm Park-gardens, S W.
Sandes, Thomas, A B Sallow Glin, Tarbert, Co Kerry
1896. §Saner, John Arthur, M Inst C E Highfield, Northwich
1896 ‡Saner, Mrs Highfield Northwich
1903. ‡Sankey, Captain H R , R E , M Inst C E Palace-chambers, 9 Bridge-street, S W
1886. ‡Sankey, Percy E 44 Russell-square, W C
1905 ‡Sargant, E B Quarry Hill, Reigate
1896 *Sargant, Miss Ethel, F L S 7 Calverley-park, Tunbridge Wells.
1907. ‡Sargent, H C Ambergate, near Derby
1886 ‡Saundby, Robert, M D 83A Edmund-street, Birmingham
1900 *SAUNDER, S A Fir Holt, Crowthorne, Berks
1903 *Saunders, Miss E R Newnham College, Cambridge.
1901 ‡*Sawers, W D 1 Athole Gardens-place, Glasgow*
1887. §SAYCE, Rev A H , M A , D D (Pres H, 1887), Professor of Assyriology in the University of Oxford Queen's College, Oxford
1906 ‡Sayer, Dr Ettie. 35 Upper Brook-street, W
1883. *Scarborough, George Whinney Field, Halifax, Yorkshire
1903 §SCARISBRICK, Sir CHARLES, J P Scarisbrick Lodge Southport
1903 ‡Scarisbrick, Lady Scarisbrick Lodge, Southport
1879. *SCHAFER, E A, LL D , D Sc , M D , F R S (PRESIDENT; GENERAL SECRETARY, 1895-1900 , Pres I, 1894 , Council, 1887-93), Professor of Physiology in the University of Edinburgh.
1888. *SCHARFF, ROBERT F , Ph D , B Sc , Keeper of the Natural History Department, National Museum, Dublin
1880. *Schemmann, Louis Carl Neueberg 12, Hamburg
1908 ‡Schrodter, Dr E 27 Breite-strasse, Dusseldorf, Germany.
1873. *SCHUSTER, ARTHUR, Ph D , F R S , F R A S (Pres A, 1892 ; Council, 1887-93) Kent House, Victoria Park, Manchester
1847 *SCLATER, PHILIP LUTLEY, M A , Ph D , F R S , F L.S , F G S , F.R.G S., F Z S (GENERAL SECRETARY, 1876-81 ; Pres D, 1875 ; Council, 1864-67, 1872-75) Odiham Priory, Winchfield.
1883. *SCLATER, W. LUTLEY, M A , F Z S Odiham Priory, Winchfield.
1905 ‡Sclater, Mrs. W. L Odiham Priory, Winchfield.

Year of Election

1913. §Scoble, Walter A., B.Sc., A.M.Inst.C.E. City and Guilds Technical College, Leonard-street, E.C.
1881. *SCOTT, ALEXANDER, M.A., D.Sc., F.R.S., F.C.S. 34 Upper Hamilton-terrace, N.W.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1889. *SCOTT, D. H., M.A., Ph.D., F.R.S., Pres.L.S. (GENERAL SECRETARY, 1900–03; Pres. K, 1896.) East Oakley House, Oakley, Hants; and Athenæum Club, Pall Mall, S.W.
1857. *SCOTT, ROBERT H., M.A., D.Sc., F.R.S., F.R.Met.S. 6 Elm Park-gardens, S.W.
1902. ‡Scott, William R., M.A., Litt.D. The University, St. Andrews, Scotland.
1895. ‡Scott-Elliot, Professor G. F., M.A., B.Sc., F.L.S. Newton, Dumfries.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1909. ‡*Scudamore, Colonel F. W. Chelsworth Hall, Suffolk.*
1895. ‡Scull, Miss E. M. L. St. Edmund's, 10 Worsley-road, Hampstead, N.W.
1890. *Searle, G. F. C., Sc.D., F.R.S. Wyncote, Hills-road, Cambridge.
1880. ‡SEDGWICK, ADAM, M.A., F.R.S. (Pres. D, 1899), Professor of Zoology in the Imperial College of Science and Technology, London. 2 Sumner-place, S.W.
1906. *See, T. J. J., A.M., Ph.D., F.R.A.S., Professor of Mathematics, U.S. Navy. Naval Observatory, Mare Island, California.
1907. §Seligmann, Dr. C. G. 36 Finchley-road, N.W.
1911. *Seligmann, Mrs. C. G. 36 Finchley-road, N.W.
1904. ‡Sell, W. J. 19 Lensfield-road, Cambridge.
1909. ‡Sellars, H. Lee. 225 Fifth-avenue, New York, U.S.A.
1888. *SENIER, ALFRED, M.D., Ph.D., F.C.S. (Pres. B, 1912.) Professor of Chemistry in University College, Galway.
1888. *SENNETT, ALFRED R., A.M.Inst.C.E. Duffield, near Derby.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1910. ‡Seton, R. S., B.Sc. The University, Leeds.
1895. *Seton-Karr, H. W. 8 St. Paul's-mansions, Hammersmith, W.
1892. *SEWARD, A. C., M.A., F.R.S., F.G.S. (Pres. K, 1903; Council, 1901–07; Local Sec. 1904), Professor of Botany in the University of Cambridge. Westfield, Huntingdon-road, Cambridge.
1899. §Seymour, Henry J., B.A., F.G.S., Professor of Geology in the National University of Ireland. Earlsfort-terrace, Dublin.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1905. *Shackleford, W. C. Burnt Green, Worcestershire.
1904. ‡Shackleton, Lieutenant Sir Ernest H., M.V.O., F.R.G.S. 14 South Learmonth-gardens, Edinburgh.
1902. ‡SHAFTESBURY, The Right Hon. the Earl of, K.P., K.C.V.O. Belfast Castle, Belfast.
1901. *Shakespear, Mrs. G. A. 21 Woodland-road, Northfield, Worcestershire.
1906. ‡Shann, Frederick. 6 St. Leonard's, York.
1878. ‡SHARP, DAVID, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
1904. ‡Sharples, George. 181 Great Cheetham-street West, Higher Broughton, Manchester.
1910. ‡Shaw, J. J. Sunnyside, Birmingham-road, West Bromwich.
1889. *Shaw, Mrs. M. S., B.Sc. Brookhayes, Exmouth.
1883. *SHAW, W. N., M.A., Sc.D., F.R.S. (Pres. A, 1908; Council, 1895–1900, 1904–07.) Meteorological Office, South Kensington, S.W.

Year of Election

1883. ‡Shaw, Mrs. W. N. 10 Moreton-gardens, South Kensington, S.W.
1904. ‡*Shaw-Phillips, Miss.* 70 *Westbourne-terrace, Hyde Park, W.*
1903. ‡Shaw-Phillips, T., J.P. The Times Library Club, 380 Oxford-street, W
1912. §Shearer, C. Clare College, Cambridge.
1905. ‡Shenstone, Miss A Sutton Hall, Barcombe, Lewes.
1905. ‡Shenstone, Mrs A. E. G. Sutton Hall, Barcombe, Lewes.
1865. ‡Shenstone, Frederick S Sutton Hall, Barcombe, Lewes.
1900. §SHEPPARD, THOMAS, F.G S The Municipal Museum, Hull.
1908 §Sheppard, W. F., Sc D, LL M Board of Education, Whitehall, S W.
1883 ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin
1883. ‡Sherlock, Mrs David. Rahan Lodge Tullamore, Dublin.
1896 ‡SHERRINGTON, C S, M D., D Sc, F R S. (Pres I, 1904; Council, 1907–), Professor of Physiology in the University of Liverpool 16 Grove-park, Liverpool.
1888 *Shickle, Rev. C. W, M A, F S A St John's Hospital, Bath.
1908 *Shickle, Miss Mabel G M 9 Cavendish-crescent, Bath.
1902 *Shillington, T. Foulkes, J P Dromart, Antrim-road, Belfast.
1883. *Shillitoe, Buxton, F.R C S 29 Sydenham-hill, S.E.
1887 *SHIPLEY, ARTHUR E, M A, D Sc, F R S (Pres. D, 1909; Council, 1904–11), Master of Christ's College, Cambridge
1909 ‡Shipley, J. W., B.A. University of Manitoba, Winnipeg, Canada.
1897. ‡SHORE, Dr LEWIS E St. John's College, Cambridge
1882 ‡SHORE, T W., M D, B.Sc., Lecturer on Comparative Anatomy at St Bartholomew's Hospital 6 Kingswood-road, Upper Norwood, S E
1901. ‡Short, Peter M, B Sc 1 Deronda-road, Herne Hill, S E.
1908 §Shorter, Lewis R, B Sc 29 Albion-street, W.
1904 *Shrubsall, F C, M A, M D 34 Lime-grove, Uxbridge-road, W.
1910 ‡Shuttleworth, T. E. 5 Park-avenue, Riverdale-road, Sheffield.
1889 ‡Sibley, Walter K, M A, M D 6 Cavendish-place, W.
1902 ‡Siddons, A W, M A. Harrow-on-the-Hill, Middlesex
1883 *Sidebotham, Edward John Erlesdene, Bowdon, Cheshire
1877 *Sidebotham, Joseph Watson Merlewood, Bowdon, Cheshire.
1873. *SIEMENS, ALEXANDER, M.Inst C.E Caxton House, Westminster, S.W.
1905. ‡Siemens, Mrs A. Caxton House, Westminster, S W
1903. *Silberrad, Dr. Oswald Buckhurst Hill, Essex.
1871 *SIMPSON, Sir ALEXANDER R, M D, Emeritus Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1863 ‡Simpson, J B, F.G.S Hedgefield House, Blaydon-on-Tyne
1909. ‡Simpson, Professor J. C. McGill University, Montreal, Canada.
1908. ‡Simpson, J. J, M A., B Sc. Zoological Department, Marischal College, Aberdeen
1901. *Simpson, Professor J Y, M.A, D Sc, F.R S.E 25 Chester-street, Edinburgh
1907. ‡Simpson, Lieut -Colonel R J S, C M G 66 Shooters Hill-road, Blackheath, S E
1909. *Simpson, Samuel, B Sc Entebbe, Uganda.
1909 ‡Simpson, Sutherland, M D Cornell University Medical College. Ithaca, New York, U.S.A.
1896. *SIMPSON, W, F G S. Catteral Hall, Settle, Yorkshire
1884. *Simpson, Professor W. J. R., C.M.G, M.D. 31 York-terrace, Regent's Park, N.W.
1909. ‡Sinclair, J. D 77 Spence-street, Winnipeg.

Year of Election

1912. §Sinclair, Sir John R. G., Bart., D.S.O. Barrock House, Wick. N.B.
1874. ‡SINCLAIR, Right Hon. THOMAS. (Local Sec. 1874.) Dunedin, Belfast.
1907. *Sircar, Dr. Amrita Lal, L.M.S., F.C.S. 51 Sankaritola, Calcutta.
1905. *SJOGREN, Professor H. Natural History Museum, Stockholm, Sweden.
1902. ‡Skeffington, J. B., M.A., LL.D. Waterford.
1906. ‡Skerry, H. A. St Paul's-square, York.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1910. §Skinner, J. C. 76 Ivy Park-road, Sheffield.
1898. ‡SKINNER, SIDNEY, M.A. (Local Sec. 1904.) South-Western Polytechnic, Manresa-road, Chelsea, S.W.
1905. *Skyrme, C. G. Baltimore, 6 Grange-road, Upper Norwood, S.E.
1887. ‡Small, Evan W., M.A., B.Sc., F.G.S. 48 Kedleston-road, Derby.
1903. *Smallman, Raleigh S. Eliot Lodge, Albemarle-road, Beckenham.
1904. ‡Smart, Edward. Benview, Craigie, Perth, N.B.
1889. *SMART, Professor WILLIAM, LL.D. (Pres. F, 1904.) Nunholme, Dowanhill, Glasgow.
1902. ‡Smedley, Miss Ida. 36 Russell-square, W.C.
1911. ‡Smiles, Samuel. The Quarry, Sanderstead-road, Sanderstead, Surrey.
1911. §Smith, A. Malins. St Audrey's Mill House, Thetford, Norfolk.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Department of Chemistry, Columbia University, New York, U.S.A.
1908. ‡Smith, Alfred. 30 Merrion-square, Dublin.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1901. *Smith, Miss Annie Lorrain. 20 Talgarth-road, West Kensington, W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, S.W.
1873. ‡Smith, C. Sidney-Sussex College, Cambridge.
1889. *Smith, Professor C. Michie, C.I.E., B.Sc., F.R.S.E., F.R.A.S. The Observatory, Kodaikanal, South India.
1910. ‡Smith, Charles. 11 Winter-street, Sheffield.
1900. §Smith, E. J., Grange House, Westgate Hill, Bradford.
1908. ‡Smith, E. Shrapnell. 7 Rosebery-avenue, E.C.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1901. §Smith, F. B. Care of A. Croxton Smith, Esq., Burlington House, Wandle-road, Upper Tooting, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1911. §Smith, F. E. Redcot, St. James's-avenue, Hampton Hill.
1912. §Smith, Rev. Frederick. The Parsonage, South Queensferry.
1897. ‡SMITH, G. ELLIOT, M.D., F.R.S. (Pres. H, 1912), Professor of Anatomy in the University of Manchester.
1911. ‡Smith, Geoffrey W., M.A., F.L.S. New College, Oxford.
1903. *SMITH, Professor H. B. LEES, M.A., M.P. The University, Bristol.
1910. §Smith, H. Bompas, M.A. King Edward VII School, Lytham.
1889. *SMITH, Sir H. LLEWELLYN, K.C.B., M.A., B.Sc., F.S.S. (Pres. F, 1910.) Board of Trade, S.W.
1860. *Smith, Heywood, M.A., M.D. 40 Portland-court, W.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
1902. ‡Smith, J. Lorrain, M.D., F.R.S., Professor of Pathology in the Victoria University, Manchester.
1903. *Smith, James. Pinewood, Crathes, Aberdeen.

Year of Election

1911. §Smith, Priestley, F.R.C S., Professor of Ophthalmology in the University of Birmingham 95 Cornwall-street, Birmingham.
1910. §Smith, Samuel. Central Library, Sheffield.
1894. §Smith, T. Walrond Care of Frank Henderson, Esq , 19 Manor-road, Sidcup, Kent.
1910. ‡Smith, W. G., B Sc , Ph.D. College of Agriculture, Edinburgh
1896 *Smith, Rev W. Hodson Newquay, Cornwall
1911. ‡Smith, W Parnell The Grammar School, Portsmouth
1885 *Smith, Watson 34 Upper Park-road, Haverstock Hill, N W
1909. ‡Smith, William. 218 Sherbrooke-street, Winnipeg, Canada.
1883 ‡SMITHELLS, ARTHUR, B Sc , F R S (Pres B, 1907 , Local Sec 1890), Professor of Chemistry in the University of Leeds
1906 §Smurthwaite, Thomas E., F R A.I 134 Mortimer-road, Kensal Rise, N W
1905. §Smuts, C P O Box 1088, Johannesburg
1909. §Smylie, Hugh 13 Donegall-square North, Belfast.
1857 *SMYTH, JOHN, M A , F C S , F R M S , M Inst C E I Milltown, Banbridge, Ireland
1908. §Smythe, J. A , Ph D , D Sc 10 Queen's-gardens, Benton, Newcastle-on-Tyne
1888 *SNAPE, H. LLOYD, D Sc , Ph D Balholm, Lathom-road, Southport
1905 ‡SODDY, F., M A , F R S The University, Glasgow
1905. ‡Sollas, Miss I B J , B Sc. Newnham College, Cambridge
1879 *SOLLAS, W J , M A , Sc D , F R S , F R S E , F G S (Pres C, 1900 , Council, 1900–03), Professor of Geology in the University of Oxford 173 Woodstock-road, Oxford
1900. *SOMERVILLE, W , D Sc , F L S , Sibthorpian Professor of Rural Economy in the University of Oxford 121 Banbury-road, Oxford
1910. *Sommerville, Duncan M. Y. 70 Argyle-street, St Andrews, N B.
1901 ‡*Sorley, Robert The Firs, Partickhill, Glasgow*
1903 ‡Soulby, R M Sea Holm, Westbourne-road, Birkdale, Lancashire
1903 ‡Southall, Henry T The Graig, Ross, Herefordshire
1865 *Southall, John Tertius Parkfields, Ross, Herefordshire
188? ‡Spanton, William Dunnett, F R C S Chatterley House, Hanley, Staffordshire
1909 ‡Sparling, Rev. J. W., D D 159 Kennedy-street, Winnipeg, Canada.
1893 *Speak, John Kirton Grange, Kirton, near Boston
1910 ‡Spearman, C Birnam, Guernsey
1912 §Speirs, Adam, B Sc Holywood, Belfast
1910 ‡Spicer, Rev E C The Rectory, Waterstock, Oxford
1864 *Spicer, Henry, B A , F L S , F G S 14 Aberdeen-park, Highbury, N
1894 ‡Spiers, A H Gresham's School, Holt, Norfolk
1864 *SPILLER, JOHN, F C S 2 St Mary's-road, Canonbury, N
1864 *Spottiswoode, W Hugh, F.C S 6 Middle New-street, Fetter-lane, E C
1909. ‡Sprague, D E 76 Edmonton-street, Winnipeg, Canada.
1854 *SPRAGUE, THOMAS BOND, M.A , LL D , F R S E 29 Buckingham-terrace, Edinburgh
1888 *Stacy, J Sargeant 164 Shoreditch, E.
1903 ‡Stallworthy, Rev George B. The Manse, Hindhead, Haslemere, Surrey
1883 *Stanford, Edward, F R G S 12–14 Long-acre, W.C
1883 ‡Stanley, Mrs Cumberlow, South Norwood, S E

Year of Election

1894. *STANSFIELD, ALFRED, D Sc McGill University, Montreal, Canada
1909. §Stansfield, Edgar. Mines Branch, Department of Mines, Ottawa, Canada.
1900. *STANSFIELD, H., D Sc, A I E.E. The University, Manchester.
1911 §Stapf, Dr Otto, F R S. Royal Gardens, Kew.
1899. ‡STARLING, E H, M D, F R S (Pres. I, 1909), Professor of Physiology in University College, London, W C
1898 ‡Stather, J W, F G S Brookside, Newland Park, Hull.
Staveley, T K Ripon, Yorkshire
1907 §Staynes, Frank 36-38 Silver-street, Leicester
1910 ‡Stead, F B 80 St. Mary's-mansions, Paddington, W.
1900 *STEAD, J E, F R S (Pres. B, 1910) Laboratory and Assay Office, Middlesbrough
1881. ‡Stead, W H Beech-road, Reigate
1892 *STEBBING, Rev THOMAS R R, M A, F R S. Ephraim Lodge, The Common, Tunbridge Wells
1896 *STEBBING, W P D, F G S 78A Lexham-gardens, W
1911 ‡Steele, L J, M I E E H M Dockyard, Portsmouth
1908. ‡Steele, Lawrence Edward, M A, M R I A 18 Crosthwaite-park East, Kingstown, Co Dublin
1912 §Steggall, J E A, M A, Professor of Mathematics in University College, Dundee
1911 ‡Stein, Sir Marc Aurel, K C I E, D Sc, D Litt Merton College, Oxford
1909 ‡Steinkopj, Max. 667 Main-street, Winnipeg, Canada.
1884 *Stephens, W. Hudson Low-Ville, Lewis County, New York, U S A
1902 ‡Stephenson, G Grianan, Glasnevin, Dublin
1910 *STEPHENSON, H K. Banner Cross Hall, Sheffield.
1911 ‡Stern, Moritz 241 Bristol-road, Birmingham
1909 ‡Stethern, G. A Fort Frances, Ontario, Canada.
1908 *Steven, Alfred Ingram, M A, B Sc 50 Onslow-road, Fairfield, Liverpool
1906 ‡Stevens, Miss C O The Plain, Foxcombe Hill, Oxford
1880 *Stevens, J Edward, LL B Le Mayals, Blackpill, R S O
1900 ‡STEVENS, FREDERICK (Local Sec 1900) Town Clerk's Office, Bradford
1905 §Stewart, A F 127 Isabella-street, Toronto, Canada
1909 ‡Stewart, David A., M D. 407 Pritchard-avenue, Winnipeg, Canada.
1875 *Stewart, James, B A, F R C P Ed Junior Constitutional Club, Piccadilly, W
1901 *Stewart, John Joseph, M A, B Sc 2 Stow Park-crescent, Newport, Monmouthshire
1901 *Stewart, Thomas St George's-chambers, Cape Town
1911. ‡Stibbs, H A Portsea Island Gas Company, Commercial-road, Portsmouth.
1876 ‡STIRLING, WILLIAM, M D, D Sc, F R S E, Professor of Physiology in the Victoria University, Manchester
1904 ‡Stobbs, J T Dunelm, Basford Park, Stoke-on-Trent.
1906 *Stobo, Mrs Annie Somerset House, Garelochhead, Dumbartonshire, N B
1901. *Stobo, Thomas. Somerset House, Garelochhead, Dumbartonshire, N B
1883 *STOCKER, W. N, M A. Brasenose College, Oxford.
1898. *Stokes, Professor George J, M A. 5 Fernhurst-villas, College-road, Cork.
1899 *Stone, Rev. F. J. Radley College, Abingdon.

Year of Election

1874. ‡Stone, J Harris, M A, F.L S, F.C S 3 Dr. Johnson's-buildings, Temple, E C
1905. ‡Stoneman, Miss Bertha, D Sc Huguenot College, Wellington, Cape Colony
1895 *Stoney, Miss Edith A 30 Chepstow-crescent, W
1908. *Stoney, Miss Florence A., M D 4 Nottingham-place, W
1878 *Stoney, G Gerald, F.R S. Oakley, Heaton road, Newcastle-upon-Tyne.
1883 ‡Stopes, Mrs 7 Denning-road, Hampstead, N W
1903. *Stopes, Marie C, D Sc, Ph D, F L S 14 Well-walk, Hampstead, N.W
1910 §Storey, Gilbert Lime Grove, Brooklands, near Manchester.
1887 *Storey, H L Bailrigg, Lancaster
1888. *Stothert, Percy K Woolley Grange, Bradford-on-Avon, Wilts
1905. *Stott, Clement H, F G S P O Box 7, Pietermaritzburg, Natal
1881. ‡STRAHAN, AUBREY, M A, F R S, F G S (Pres C, 1904) Geological Museum, Jermyn-street, S W
1905 ‡Strange, Harold F. P O Box 2527, Johannesburg
1908. *Stratton, F J M, M A Gonville and Caius College, Cambridge
1906. *Stromeyer, C E 9 Mount-street, Albert-square, Manchester
1883. §Strong, Henry J, M D Colonnade House, The Steyne, Worthing
1898. *Strong, W M, M D 3 Champion-park, Denmark Hill, S E
1887 *Stroud, H, M A, D Sc, Professor of Physics in the Armstrong College, Newcastle-upon-Tyne
1887. *STROUD, WILLIAM, D Sc, Professor of Physics in the University of Leeds. Care of Messrs. Barr & Stroud, Anniesland, Glasgow.
1876 *Stuart, Charles Maddock, M A St Dunstan's College, Catford, S E
1872 *Stuart, Rev Canon Edward A, M A The Precincts, Canterbury
1885 ‡Stump, Edward C Malmesbury, Polefield, Blackley, Manchester
1909. ‡Stupart, R. F. Meteorological Service, Toronto, Canada
1879 *Styring, Robert Brinkcliffe Tower, Sheffield
1891. *Sudborough, Professor J J, Ph D, D Sc University College of Wales, Aberystwyth
1902. §Sully, H T Scottish Widows-buildings, Bristol
1898 §Sully, T. N Avalon House, Queen's-road, Weston-super-Mare
1911 ‡Summers, A H, M A 16 St Andrew's-road, Southsea
1887. *Sumpner, W E, D Sc. Technical School, Suffolk-street, Birmingham
1908. §Sutherland, Alexander School House, Gersa, Watten, Caithness
1911 §Sutton, Leonard, F L S Hillside, Reading
1911 ‡Sutton, W L, F.I C Hillcroft, Eaton, Norwich
1903 ‡Swallow, Rev R D, M A Chigwell School, Essex
1881 §SWAN, Sir JOSEPH WILSON, M A, D Sc, F R S Overhill Warlingham, Surrey.
1905 ‡Swan, Miss Mary E Overhill, Warlingham, Surrey
1911 *SWANN, Dr W. F G 435 Glossop-road, Sheffield
1897. ‡Swanston, William, F.G S Mount Collyer Factory, Belfast
1908. ‡Swanzy, Sir Henry R, M D 23 Merrion-square, Dublin
1887 §SWINBURNE, JAMES, F R S, M Inst C.E 82 Victoria-street, S W
1870. *Swinburne, Sir John, Bart Capheaton Hall, Newcastle-upon-Tyne
1902. *Sykes, Miss Ella C Elcombs, Lyndhurst, Hampshire
1887. *Sykes, George H, M A., M Inst C E, F S.A Glencoe, 64 Elmbourne-road, Tooting Common, S.W.
1896. *Sykes, Mark L, F.R M S 10 Headingley-avenue, Leeds
1902. *Sykes, Major P. Molesworth, C M.G. Elcombs, Lyndhurst, Hampshire.

Year of Election.

1906 ‡Sykes, T. P., M.A 4 Gathorne-street, Great Horton, Bradford.
1903 §Symington, Howard W. Brooklands, Market Harborough.
1885. ‡SYMINGTON, JOHNSON, M D, F R S, F R S E (Pres H, 1903), Professor of Anatomy in Queen's University, Belfast.
1908 ‡Synnott, Nicholas J Furness, Naas, Co Kildare

1910 *Tait, John, M.D, D Sc 2 Parkside-terrace, Edinburgh.
1912. §Talbot, P. Amaury Abbotsmorton, Inkberrow, Worcestershire
1904 §Tallack, H T Clovelly, Birdhurst-road, South Croydon.
1903 *Tanner, Miss Ellen G Parkside, Corsham, Wilts
1890 ‡TANNER, H W LLOYD, D Sc, F R S. (Local Sec 1891.) University College, Cardiff
1892. *TANSLEY, ARTHUR G, M A, F L S Grantchester, near Cambridge
1908. ‡TARLETON, FRANCIS A, LL D 24 Upper Leeson-street, Dublin
1861. *Tarratt, Henry W. 2c Oxford and Cambridge-mansions, Hyde Park, W.
1902. ‡Tate, Miss Rantalard, Whitehouse, Belfast.
1908 ‡Taylor, Rev Campbell, M A United Free Church Manse, Wigtown, Scotland
1887 ‡Taylor, G H Holly House, 235 Eccles New-road, Salford
1898. ‡Taylor, Lieut-Colonel G. L Le M 6 College-lawn, Cheltenham
1881. *Taylor, H A 12 Melbury-road, Kensington, W
1906 ‡Taylor, H Dennis Stancliffe, Mount-villas, York
1884 *TAYLOR, H M, M A, F R S Trinity College, Cambridge
1882 *Taylor, Herbert Owen, M D Oxford-street, Nottingham
1860 *Taylor, John, M Inst C E 6 Queen Street-place, E C
1906 §Taylor, Miss M R Newstead, Blundellsands
1884 *Taylor, Miss S Oak House, Shaw, near Oldham
1894. *Taylor, W W, M A 66 St John's-road, Oxford
1901. *Teacher, John H, M B 32 Kingsborough-gardens, Glasgow
1858 ‡TEALE, THOMAS PRIDGIN, M A, F R S 38 Cookridge-street, Leeds
1885 ‡TEALL, J J H, M A, D Sc, F R S, F G S (Pres C, 1893; Council, 1894–1900, 1909–), Director of the Geological Survey of the United Kingdom The Museum, Jermyn-street, S W
1906. *Teape, Rev W M, M A South Hylton Vicarage, Sunderland
1910. ‡Tebb, W Scott, M A, M D. 15 Finsbury-circus, E C
1879. ‡Temple, Lieutenant G T., R.N, F R G S Solheim, Cumberland Park, Acton, W
1896. *Terry, Rev T R, M A, F R A S The Rectory, East Ilsley, Newbury, Berkshire.
1892. *Tesla, Nikola 45 West 27th-street, New York, U S A
1883. ‡Tetley, C F The Brewery, Leeds
1883 ‡Tetley, Mrs C F The Brewery, Leeds
1882 *THANE, GEORGE DANCER, LL D, Professor of Anatomy in University College, London, W C
1871. ‡THISELTON-DYER, Sir W. T, K C M G, C I E, M A, B Sc, Ph.D, LL D, F R S, F L S (Pres D, 1888, Pres K, 1895; Council, 1885–89, 1895–1900) The Ferns, Witcombe, Gloucester
1906 *Thoday, D The University, Manchester
1906. *Thoday, Mrs. M G 5 Redclyffe-road, Withington, Manchester.
1870. ‡Thom, Colonel Robert Wilson, J P Brooklands, Lord-street West, Southport
1891. *Thomas, Miss Clara Pencerrig, Builth.

Year of Election

1903. *THOMAS, Miss ETHEL N, B Sc 3 Downe-mansions, Gondar-gardens, West Hampstead, N W.
1913. §Thomas, H H, M A, B Sc, F G.S 28 Jermyn-street, S.W.
1910. *Thomas, H. Hamshaw. Botany School, Cambridge.
1880. *Thomas, Joseph William, F C S Overdale, Shortlands, Kent
1899. *Thomas, Mrs. J W Overdale, Shortlands, Kent
1902 *Thomas, Miss M Beatrice Girton College, Cambridge
1883. ‡Thomas, Thomas H 45 The Walk, Cardiff
1904 *Thomas, William, F R G S Bryn-heulog, Merthyr Tydfil
1891. *Thompson, Beeby, F C S, F G S 67 Victoria-road, Northampton
1888 *Thompson, Claude M, M A, D Sc, Professor of Chemistry in University College, Cardiff 38 Park-place, Cardiff
1885 §THOMPSON, D'ARCY W, C B, B A (Pres D, 1911, Local Sec, 1912), Professor of Zoology in University College, Dundee
1896. *Thompson, Edward P Paulsmoss, Whitchurch, Salop
1907. *Thompson, Edwin 25 Sefton-drive, Liverpool
1883 *Thompson, Francis Eversley, Haling Park-road, Croydon
1904 *Thompson, G R, B Sc, Principal of and Professor of Mining in the South African School of Mines, Johannesburg
1912 *Thompson, Rev H Percy Kippington Vicarage, Sevenoaks
1893 *Thompson, Harry J, M Inst C E Tregarthen, Garland's-road, Leatherhead
1883 *Thompson, Henry G, M D 86 Lower Addiscombe-road, Croydon.
1876 *Thompson, Richard Dringcote, The Mount, York
1876 ‡THOMPSON, SILVANUS PHILLIPS, B A, D Sc, F R S, F R A S (Pres G, 1907, Council, 1897-99, 1910-), Principal of and Professor of Physics in the City and Guilds of London Technical College, Leonard-street, Finsbury, E C
1883 *Thompson, T H Oldfield Lodge, Gray road, Bowdon, Cheshire
1896 *THOMPSON, W H, M D, D Sc (Local Sec 1908), King's Professor of Institutes of Medicine (Physiology) in Trinity College, Dublin 14 Hatch-street, Dublin
1911 §Thompson, Mrs W H 328 Assiniboine-avenue, Winnipeg
1905 ‡*Thompson, William Parkside, Doncaster-road, Rotherham*
1912 §Thompson, William Bruce Thornbank, Dundee
1912 §Thoms, Alexander 7 Playfair-terrace, St Andrews
1894 ‡THOMSON, ARTHUR, M A, M D, Professor of Human Anatomy in the University of Oxford Exeter College, Oxford
1912 §Thomson, D C 'Courier' Buildings, Dundee
1909 *Thomson, E. 22 Monument-avenue, Swampscott, Mass, U.S.A.
1906 §Thomson, F Ross, F G S. Hensill, Hawkhurst, Kent
1890 *THOMSON, Professor J ARTHUR, M A, F R S E Castleton House, Old Aberdeen.
1883 ‡THOMSON, Sir J J, O M, M A, Sc D, D Sc, F R S (PRESIDENT, 1909, Pres A, 1896, Council, 1893–95), Professor of Experimental Physics in the University of Cambridge Trinity College, Cambridge
1901. ‡*Thomson, Dr J. T. Kilpatrick.* 148 *Norfolk-street, Glasgow*
1889 *Thomson, James, M A 22 Wentworth-place, Newcastle-upon-Tyne
1902. ‡Thomson, James Stuart. 29 Ladysmith-road, Edinburgh.
1891. ‡Thomson, John. Westover, Mount Ephraim-road, Streatham, S W.
1871. *THOMSON, JOHN MILLAR, LL D, F R S. (Council, 1895–1901), Professor of Chemistry in King's College, London. 18 Lansdowne-road, Holland Park, W.

Year of Election

1874 §**Thomson, William**, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880 §Thomson, William J. Ghyllbank, St. Helens.
1906 ‡Thornely, Miss A. M. M. Oaklands, Langham-road, Bowdon, Cheshire.
1905 *Thornely, Miss L. R. Nunclose, Grassendale, Liverpool.
1898 ***Thornton, W. M.**, D.Sc., Professor of Electrical Engineering in the Armstrong College, Newcastle-on-Tyne.
1902. ‡Thornycroft, Sir John I., F.R.S., M.Inst.C.E. Eyot Villa, Chiswick Mall, W.
1903. ‡Thorp, Edward. 87 Southbank-road, Southport.
1881. ‡Thorp, Fielden. Blossom-street, York.
1881 *Thorp, Josiah. 24 Manville-road, New Brighton, Cheshire.
1898. §Thorp, Thomas. Moss Bank, Whitefield, Manchester.
1898 ‡**Thorpe, Jocelyn Field**, Ph.D., F.R.S. Sheffield University.
1871. ‡**Thorpe, Sir T. E.**, C.B., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. (Pres. B, 1890; Council, 1886–92.) Whinfield, Salcombe, South Devon.
1899 §**Threlfall, Richard**, M.A., F.R.S. Oakhurst, Church-road, Edgbaston, Birmingham.
1896 §**Thrift, William Edward**, M.A. (Local Sec. 1908), Professor of Natural and Experimental Philosophy in the University of Dublin. 80 Grosvenor-square, Rathmines, Dublin.
1907 ‡*Thwaites, R. E. 28 West-street, Leicester.*
1889 ‡Thys, Colonel Albert. 9 Rue Briderode, Brussels.
1873 ***Tiddeman, R. H.**, M.A., F.G.S. 298 Woodstock-road, Oxford.
1905 ‡Tietz, Heinrich, B.A., Ph.D. South African College, Cape Town.
1874 ‡**Tilden, Sir William A.**, D.Sc., F.R.S., F.C.S. (Pres. B, 1888; Council, 1898–1904), Professor of Chemistry in the Imperial College of Science, London. The Oaks, Northwood, Middlesex.
1899 ‡Tims, H. W. Marett, M.A., M.D., F.L.S. 8 Brookside, Cambridge.
1902 ‡Tipper, Charles J. R., B.Sc. 21 Greenside, Kendal.
1905 ‡Tippett, A. M., M.Inst.C.E. Cape Government Railways, Cape Town.
1911 §Tizard, Henry T. Oriel College, Oxford.
1900 §Tocher, J. F., B.Sc., F.I.C. Crown-mansions, 41½ Union-street, Aberdeen.
1912 §Todd, John A. Machuim, Laweis, Aberfeldy.
1907 ‡Todd, Professor J. L. MacDonald College, Quebec, Canada.
1889 §Toll, John M. 49 Newsham-drive, Liverpool.
1875 ‡Torr, Charles Hawley. 35 Burlington-road, Sherwood, Nottingham.
1909. ‡Tory, H. M. Edmonton, Alberta, Canada.
1912 §Tosh, Elmsl e. 11 Reform-street, Dundee.
1901 ‡Townsend, J. S., M.A., F.R.S., Professor of Physics in the University of Oxford. New College, Oxford.
1876 ***Trail, J. W. H.**, M.A., M.D., F.R.S., F.L.S. (Pres. K, 1910), Regius Professor of Botany in the University of Aberdeen.
1883 ‡**Traill, A.**, M.D., LL.D., Provost of Trinity College, Dublin. Ballylough, Bushmills, Ireland.
1870 ‡**Traill, William A.** Giant's Causeway Electric Tramway, Portrush, Ireland.
1902. ‡*Travers, Ernest J. Dunmurry, Co. Antrim.*
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1908 §Treen, Henry M., B.Sc. Wicken, Soham, Cambridge.
1908. ‡Tremain, Miss Caroline P., B.A. Alexandra College, Dublin.

Year of Election

1910. §Tremearne, Major A. J N., B.A. 105 Blackheath Park, S.E.
1911. §Tremearne, Mrs , LL A. 105 Blackheath Park, S.E.
1887. *Trench-Gascoigne, Mrs. F. R. Lotherton Hall, Parlington, Aberford, Leeds.
1903 ‡Trenchard, Hugh. The Firs, Clay Hill, Enfield
1908 ‡Tresilian, R. S. Cumnor, Eglington-road, Dublin
1905. ‡Trevor-Battye, A , M.A , F L.S., F.R.G S. Stoner Hill, Petersfield, Hants.
1871. ‡Trimen, Roland, M.A., F.R.S., F.L.S , F.Z.S. Fawley, Onslow-crescent, Woking.
1902 ‡Tristram, Rev. J F , M.A , B Sc. 20 Chandos-road, Chorlton-cum-Hardy, Manchester
1884. *Trotter, Alexander Pelham 8 Richmond-terrace, Whitehall, S.W
1887 *Trouton, Frederick T , M A , Sc.D , F R S (Council, 1911–), Professor of Physics in University College, W C
1898. *Trow, Albert Howard, D Sc., F L S , Professor of Botany in University College, Cardiff 50 Clive-road, Penarth.
1885. *Tubby, A. H., F R C S 68 Harley-street, W
1847. *Tuckett, Francis Fox Frenchay, Bristol
1905. §Turmeau, Charles Claremont, Victoria Park, Wavertree, Liverpool
1912. §Turnbull, John. City Chambers, Dundee.
1901. §Turnbull, Robert, B Sc Department of Agriculture and Technical Instruction, Dublin
1893. ‡Turner, Dawson, M.D., F.R.S E. 37 George-square, Edinburgh
1894. *Turner, H. H , M A., D Sc , F R S , F.R A S (Pres A, 1911), Professor of Astronomy in the University of Oxford The Observatory, Oxford
1905 ‡Turner, Rev. Thomas St. Saviour's Vicarage, 50 Fitzroy-street, W.
1886 *Turner, Thomas, M Sc , A R S M , F.I C , Professor of Metallurgy in the University of Birmingham Springfields, Upland-road, Selly Hill, Birmingham.
1863. *Turner, Sir William, K C.B , LL D , D C L , F R S , F.R S E. (President, 1900 ; Pres H, 1889, 1897), Principal of the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1910. §Turner, W. E. S. The University, Sheffield.
1890 *Turpin, G S , M A , D Sc High School, Nottingham
1907. §Tutton, A. E H , M A , D Sc., F.R S (Council, 1908–12) Duart, Yelverton, South Devon.
1886 *Twigg, G H 1 & 2 Ludgate-hill, Birmingham.
1899. ‡Twisden, John R , M A 14 Gray's Inn-square, W C
1907. §Twyman, F. 75a Camden-road, N W.
1865 ‡Tylor, Sir Edward Burnett, D C.L., LL.D , F R S (Pres H 1884 , Council, 1896–1902) Linden, Wellington, Somerset.
1911. *Tyndall, A M., M.Sc. The University, Bristol.
1883. ‡Tyrer, Thomas, F C S. Stirling Chemical Works, Abbey-lane, Stratford, E
1912. §Tyrrell, G. W. Geological Department, The University, Glasgow.

1884. *Underhill, G E , M A. Magdalen College, Oxford.
1903. ‡Underwood, Captain J C 60 Scarisbrick New-road, Southport
1908. §Unwin, Ernest Ewart, M.Sc. Grove House, Leighton Park School, Reading.
1883. §Unwin, John. Eastcliffe Lodge, Southport

Year of Election

1876 *UNWIN, W. C, F R.S, Pres Inst C E. (Pres. G, 1892; Council, 1892–99) 7 Palace Gate-mansions, Kensington, W.
1909. ‡Urquhart, C. 239 Smith-street, Winnipeg, Canada.
1902 §Ussher, R J. Cappagh House, Cappagh, Co Waterford.
1880 ‡USSHER, W A E, F G S 28 Jermyn-street, S W
1905 ‡Uttley, E. A, Electrical Inspector to the Rhodesian Government, Bulawayo

1887 *Valentine, Miss Anne The Elms, Hale, near Altrincham
1912 §Valentine, C W 103 Magdalen-green, Dundee
1908 ‡Valera, Edward de University College, Blackrock, Dublin.
1865 *VARLEY, S ALFRED Arrow Works, Jackson-road, Holloway, N
1907. §VARLEY, W MANSERGH, M A, D Sc, Ph D Morningside, Eaton-crescent, Swansea.
1903 †Varwell, H B Sittaford, West-avenue Exeter
1909 *Vassall, H., M A The Priory, Repton, Burton-on-Trent
1907 §Vaughan, Arthur, M A, D Sc, F G S, Lecturer in Geology at the University of Oxford The Museum Oxford
1905 ‡Vaughan, E. L Eton College, Windsor
1881 ‡VELEY, V H, M A, D Sc, F R S 8 Marlborough-place, St. John's Wood, N W
1883 *Verney, Lady Plas Rhoscolyn, Holyhead
1904 *Vernon, H M, M A, M D 22 Norham-road, Oxford.
1896 *Vernon, Thomas T Shotwick Park, Chester
1896 *Vernon, William Shotwick Park, Chester
1890 *Villamil, Lieut-Colonel R de, R E Carlisle Lodge, Rickmansworth
1906 *VINCENT, J H, M A, D Sc L C C Paddington Technical Institute, Saltram-crescent, W
1899 *VINCENT, SWALE, M D, D Sc (Local Sec 1909), Professor of Physiology in the University of Manitoba, Winnipeg. Canada
1883 *VINES, SYDNEY HOWARD, M A, D Sc, F R S, F L S (Pres K, 1900, Council, 1894–97), Professor of Botany in the University of Oxford Headington Hill, Oxford
1902 ‡Vinycomb, T B Sinn Fein, Shooters Hill, S E
1888 *Voght, Mrs Southall Manor, Southall
1904 §Volterra, Professor Vito Regia Universita, Rome

1904 §Wace, A J B Pembroke College, Cambridge
1902 ‡Waddell, Rev C H The Vicarage, Grey Abbey, Co Down
1909 ‡Wadge, Herbert W., M D 754 Logan-avenue. Winnipeg, Canada
1888. ‡Wadworth, H A Breinton Court, near Hereford
1890 §WAGER, HAROLD W T, F R S, F L S (Pres K, 1905) Hendre, Horsforth-lane, Far Headingley, Leeds
1900 ‡Wagstaff, C J L., B A. Haberdashers' School, Cricklewood, N W
1902 ‡Wainwright, Joel Finchwood, Marple Bridge, Stockport
1906 ‡Wakefield, Charles Heslington House, York
1905 §Wakefield, Captain E W Stricklandgate House, Kendal
1894 ‡WALFORD, EDWIN A, F G S 21 West Bar, Banbury
1882 *Walkden, Samuel, F R Met S. Rockleigh, Bury Head-road, Brixham, Devon
1893 ‡Walker, Alfred O, F L S Ulcombe-place, Maidstone, Kent
1890 ‡Walker, A Tannett The Elms, Weetwood, Leeds
1901 *Walker, Archibald, M A, F I C. Newark Castle, Ayr, N B
1897. *WALKER, Sir EDMUND, C V O., D.C L, F.G S (Local Sec 1897) Canadian Bank of Commerce, Toronto, Canada

Year of Election

1904. §Walker, E. R. Nightingales, Adlington, Lancashire
1911. *Walker, E. W. Ainley, M A. University College, Oxford.
1891. ‡Walker, Frederick W. Tannett. Carr Manor, Meanwood, Leeds.
1894. *WALKER, G. T, M.A., D Sc, F R S., F R.A S Red Roof, Simla, India.
1897. ‡Walker, George Blake, M.Inst.C.E. Tankersley Grange, near Barnsley
1906. ‡Walker, J. F E Gelson, B A. 45 Bootham, York
1894. *WALKER, JAMES, M A 30 Norham-gardens, Oxford
1910. *WALKER, JAMES, D Sc., F.R S (Pres B, 1911), Professor of Chemistry in the University of Edinburgh. 5 Wester Coates-road, Edinburgh.
1906 §Walker, Dr Jamieson 37 Charnwood-street, Derby
1909 ‡Walker, Lewie D. Lieberose, Monteith-road, Cathcart, Glasgow.
1912. §Walker, Miss M. L. Gray Lodge, 9 Wellington-street, Dundee.
1907. ‡Walker, Philip F, F R G S. 36 Prince's-gardens, S W.
1909. §Walker, Mrs. R. 3 Riviera-terrace, Rushbrooke, Queenstown, Co. Cork.
1908 *Walker, Robert. Ormidale, Combe Down, Bath.
1888. ‡Walker, Sydney F. 1 Bloomfield-crescent, Bath
1896. §Walker, Colonel William Hall, M P Gateacre. Liverpool.
1910. ‡Wall, G P, F.G S 32 Collegiate-crescent, Sheffield.
1883 ‡Wall, Henry 14 Park-road, Southport
1911. §WALL, THOMAS F, D Sc, Assoc M Inst C E The University, Birmingham
1863. ‡WALLACE, ALFRED RUSSEL, O M, D C L, F R S, F L S, F R G.S. (Pres D. 1876; Council, 1870–72) Broadstone, Wimborne, Dorset
1905 ‡Wallace, R W. 2 Harcourt-buildings, Temple, E C.
1901. ‡Wallace, William, M A, M D 25 Newton-place, Glasgow
1887. *WALLER, AUGUSTUS D, M D, F R S (Pres I, 1907) 32 Grove End-road, N W
1905. §Waller, Mrs 32 Grove End-road, N W
1889. *Wallis, Arnold J, M A, Corpus Christi College, Cambridge.
1895. ‡WALLIS, E WHITE, F S S Royal Sanitary Institute and Parkes Museum, 90 Buckingham Palace-road, S W.
1894. *WALMISLEY, A. T, M Inst C E. 9 Victoria-street, Westminster, S W.
1891 §Walmsley, R M., D Sc Northampton Institute, Clerkenwell, E C
1908 ‡Walsh, John M Pleona Park-avenue, Sidney-parade, Dublin
1903 ‡Walsh, W. T. H. Kent Education Committee, Caxton House Westminster, S W.
1895. ‡WALSINGHAM, The Right Hon Lord, LL D, F R S Merton Hall Thetford.
1902. *Walter, Miss L Edna 38 Woodberry grove, Finsbury Park, N
1904 *Walters, William, jun Albert House, Newmarket.
1887. ‡WARD, A. W., M A., Litt.D, Master of Peterhouse, Cambridge.
1911. ‡Ward, A. W. Town Hall, Portsmouth.
1881. §Ward, George, F C S. Buckingham-terrace, Headingley, Leeds.
1905. ‡Warlow, Dr G. P. 15 Hamilton-square, Birkenhead.
1884 *Warner, James D 199 Baltic-street, Brooklyn, U S A.
1887. ‡WARREN, Lieut General Sir CHARLES, R E, K C B, G C M G, F R S, F R G S (Pres E, 1887.) Athenæum Club, S W.
1913. §Warren, William Henry, LL D., M Sc, M Inst C E, Challis Professor of Engineering in the University of Sydney, New South Wales, Australia.
1875. *WATERHOUSE, Major General J. Hurstmead, Eltham, Kent.

Year of Election

1905 ‡Watermeyer, F. S, Government Land Surveyor. P.O. Box 973, Pretoria, South Africa

1904 ‡*Waters, A. H., B A* 48 *Devonshire-road, Cambridge.*

1900 ‡Waterston, David, M.D, F R S E King's College, Strand, W.C.

1909. §Watkinson, Professor W. H. The University, Liverpool.

1884 ‡Watson, A G, D C L Uplands, Wadhurst, Sussex

1901. *WATSON, ARNOLD THOMAS, F.L S Southwold, Tapton Crescent-road, Sheffield.

1886. *Watson, C. J. Alton Cottage, Botteville-road, Acock's Green, Birmingham

1909. §WATSON, Colonel Sir C M., K C M G, C B, R E, M A. (Pres E, 1912) 16 Wilton-crescent, S W.

1906 ‡*Watson, D M. S* *Windlehurst, Anson-road, Victoria Park, Manchester*

1909. ‡Watson, Ernest Ansley, B.Sc. Alton Cottage, Botteville-road, Acock's Green, Birmingham

1892 ‡Watson, G, M Inst C E 5 Ruskin-close, Hampstead-way, N.W.

1885. ‡Watson, Deputy Surgeon-General G. A Hendre, Overton Park, Cheltenham

1906 *Watson, Henry Angus. 3 Museum-street, York.

1894 *WATSON, Professor W., D Sc, F.R S 7 Upper Cheyne-row, S W.

1879 *WATSON, WILLIAM HENRY, F C S, F.G S. Braystones House, Beckermet, Cumberland

1901 ‡Watt, Harry Anderson, M P. Ardenslate House, Hunter's Quay Argyllshire

1875 *WATTS, JOHN, B A, D Sc Merton College, Oxford

1873 *WATTS, W MARSHALL, D Sc Shirley, Venner-road, Sydenham, S E

1883 *WATTS, W W, M A, M Sc, F R S, F G S (Pres C, 1903; Council, 1902-09), Professor of Geology in the Imperial College of Science and Technology, London, S W

1870 ‡Watts, William, M Inst C E, F G S Kenmore, Wilmslow, Cheshire.

1911 §Waxweiler, Professor E Solvay Institute, Brussels

1905 ‡Way, W A, M A The College, Graaf Reinet, South Africa.

1907 ‡Webb, Wilfred Mark Odstock, Hanwell, W

1910 ‡Webster, Professor Arthur G Worcester, Massachusetts, U S A

1909 †Webster, William, M D 1252 Portage-avenue, Winnipeg, Canada

1908 §Wedderburn, Ernest Maclagan, F R S E 7 Dean Park-crescent, Edinburgh

1903 ‡Weekes, R W, A M Inst C E 65 Hayes-road, Bromley, Kent

1890 *WEISS, F ERNEST, D Sc, F L S (Pres K, 1911), Professor of Botany in the Victoria University, Manchester

1905 ‡Welby, Miss F A Hamilton House, Hall-road, N W.

1902 ‡Welch, R. J 49 Lonsdale-street, Belfast.

1894 ‡Weld, Miss 119 Iffley-road, Oxford.

1880 *Weldon, Mrs. Merton Lea, Oxford

1908 ‡Welland, Rev C N Wood Park, Kingstown, Co Dublin

1881 §Wellcome, Henry S Snow Hill-buildings, E C

1911 ‡WELLDON, Right Rev J E C, D D. (Pres L, 1911) The Deanery, Manchester

1908 ‡*Wellisch, E. M* 17 *Park-street, Cambridge*

1881 ‡Wells, Rev Edward, M A West Dean Rectory, Salisbury

1911. *Welsford, Miss E J The University, Leeds

Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.

1864. *Were, Anthony Berwick. The Limes, Walland's Park, Lewes.

Year of Election

1886 *Wertheimer, Julius, D Sc , B A , F I.C , Dean of the Faculty of Engineering in the University of Bristol

1910. §West, G. S , M.A., D.Sc., Professor of Botany in the University of Birmingham.

1900 §WEST, WILLIAM, F L S. 26 Woodville-terrace, Horton-lane, Bradford

1903 §Westaway, F W. 1 Pemberley-crescent, Bedford

1882 *Westlake, Ernest, F G S Fordingbridge, Salisbury.

1900. ‡Wethey, E R , M A., F.R G S. 4 Cunliffe-villas, Manningham, Bradford

1909. ‡Wheeler, A. O , F.R.G.S. The Alpine Club of Canada, Sidney, B C , Canada.

1878 *Wheeler, W H , M.Inst C E 4 Hope-park, Bromley, Kent.

1888 §Whelen, John Leman 23 Fairhazel-gardens, N W

1893 *WHETHAM, W C D , M A , F R S Upwater Lodge, Cambridge.

1888 *Whidborne, Miss Alice Maria Charanté, Torquay

1912 §Whiddington, R St John's College, Cambridge

1912 *Whipple, F J , M A Meteorological Office. South Kensington, S W

1898. *WHIPPLE, ROBERT S Scientific Instrument Company, Cambridge

1859. *WHITAKER, WILLIAM, B A , F R S , F G S (Pres C, 1895 , Council, 1890-96) 3 Campden-road, Croydon

1884. ‡Whitcher, Arthur Henry Dominion Lands Office, Winnipeg, Canada

1897. ‡Whitcombe, George The Wotton Elms, Wotton, Gloucester

1886 ‡WHITE, A SILVA. Clarendon Lodge, St. John's-gardens, Holland Park, W.

1908. ‡White, Mrs A Silva Clarendon Lodge, St John's-gardens, Holland Park, W

1911 ‡White, Miss E L , M A Day Training College, Portsmouth

1904 ‡White, H Lawrence, B A 33 Rossington-road, Sheffield

1885 *White, J. Martin Balruddery, Dundee

1910 *White, Mrs Jessie, D Sc , B A 149 Gordon-mansions, W C

1912. §White, R G , M Sc 8 Whitehall-place, S W

1897. *WHITE, Sir W. H , K C.B , F R S (PRESIDENT ELECT , Pres. G. 1899, 1909 , Council, 1897-1900, 1910-12) Cedarcroft, Putney, Heath, S W.

1877. *White, William 20 Hillersdon-avenue, Church-road, Barnes, S W

1904 ‡WHITEHEAD, J. E L , M A. (Local Sec 1904) Guildhall, Cambridge.

1905. ‡Whiteley, Miss M A , D Sc. Imperial College of Science and Technology, S W

1893 §Whiteley, R Lloyd, F C S., F I C Municipal Science and Technical School, West Bromwich

1907. *Whitley, E 13 Linton-road, Oxford

1905. *Whitmee, H. B P.O Box 470, Durban, Natal.

1891 ‡Whitmell, Charles T , M A , B Sc Invermay, Hyde Park, Leeds.

1897 ‡WHITTAKER, E T , M A , F R S , Professor of Mathematics in the University of Edinburgh

1901 ‡Whitton, James City Chambers, Glasgow

1905. §Wibberley, C , M V O Solheim, Branstone-road, Kew Gardens, Surrey

1913. §Wicksteed, Rev. Philip H Childrey, Wantage, Berkshire

1912 §Wight, Dr. J Sherman. 30 Schermerhorn-street, Brooklyn, U S.A.

1889. *WILBERFORCE, L R., M A , Professor of Physics in the University of Liverpool.

1887. *WILDE, HENRY, D.Sc., D.C.L., F.R S. The Hurst, Alderley Edge, Cheshire.

Year of Election

1910. §Wilkins, C. F. Lower Division, Eastern Jumna Canal, Delhi.
1905. ‡Wilkins, R. F. Thatched House Club, St. James's-street, S.W.
1904. §Wilkinson, Hon. Mrs Dringhouses Manor, York.
1900. §Wilkinson, J. B. Holme-lane, Dudley Hill, Bradford.
1903 ‡Willett, John E. 3 Park-road, Southport.
1904. *Williams, Miss Antonia 6 Sloane-gardens, S.W.
1905. §Williams, Gardner F 2201 R-street, Washington, D C., U S A.
1883. ‡Williams, Rev H. Alban, M A Sheering Rectory, Harlow, Essex.
1861. *Williams, Harry Samuel, M A, F R A S 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams Llangibby Rectory, near Newport, Monmouthshire
1891. §Williams, J. A B, M Inst C.E Bloomfield, Branksome Park, Bournemouth
1883 *Williams, Mrs J Davies 5 Chepstow-mansions, Bayswater, W.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke-vale, Clifton, Bristol.
1901. *Williams, Miss Mary 6 Sloane-gardens, S W.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff
1883 ‡Williams, T H 27 Water-street, Liverpool
1877. *WILLIAMS, W CARLETON, F C S Broomgrove, Goring-on-Thames.
1906 ‡*Williams, W. F Lobb.* 32 *Lowndes-street, S W*
1857. ‡WILLIAMSON, BENJAMIN, M A, D C.L, F R S Trinity College, Dublin
1894. *Williamson, Mrs. Janora. 18 Rosebery-gardens, Crouch End, N.
1910. ‡Williamson, K. B., Central Provinces, India. Care of Messrs. Grindlay & Co., 54 Parliament-street, S.W.
1895. ‡WILLINK, W. (Local Sec 1896.) 14 Castle-street, Liverpool
1895 ‡Willis, John C, M A, F L S Jardin Botanico, Rio de Janeiro
1896 ‡WILLISON, J S. (Local Sec 1897) Toronto, Canada
1899. §Willson, George. Lendarac, Sedlescombe-road, St Leonards-on-Sea
1899. §Willson, Mrs George Lendarac, Sedlescombe-road, St Leonards-on-Sea
1911. *Wilmott, A. J., B A Natural History Museum, S W.
1911. §Wilsmore, Dr N T M 126 Walm-lane, Willesden Green, N.W.
1911. §Wilsmore, Mrs 126 Walm-lane, Willesden Green, N W.
1908. §Wilson, Miss Grove House, Paddock, Huddersfield
1901. ‡Wilson, A Belvoir Park, Newtownbreda, Co Down
1878 ‡Wilson, Professor Alexander S, M A, B Sc. United Free Church Manse, North Queensferry.
1905 §Wilson, A W P O Box 24, Langlaagte, South Africa
1907. §Wilson, A W Low Slack, Queen's-road, Kendal
1903. ‡Wilson, C T R, M A, F R S Sidney Sussex College, Cambridge.
1894. *Wilson, Charles J, F I C, F C S 14 Suffolk-street, Pall Mall, S.W
1904. §Wilson, Charles John, F R.G S. Deanfield, Hawick, Scotland.
1904. §Wilson, David. M D Grove House, Paddock, Huddersfield.
1912. *Wilson, David Alec 1 Broomfield-road, Ayr.
1900. *Wilson, Duncan R. 44 Whitehall-court, S.W.
1895. ‡Wilson, Dr Gregg Queen's University, Belfast.
1901. ‡Wilson, Harold A., M A, D Sc, F.R S, Professor of Physics in McGill University, Montreal, Canada.
1902. *Wilson, Harry, F.I.C. 32 Westwood-road, Southampton.
1879. ‡Wilson, Henry J, M.P. Osgathorpe Hills, Sheffield.
1910. *Wilson, J. S. 29 Denbigh-street, S.W.
1908. §Wilson, Professor James, M A., B.Sc. 40 St. Kevin's-park, Dartry-road, Dublin.

Year of Election

1879. ‡Wilson, John Wycliffe Easthill, East Bank-road, Sheffield.
1901. *Wilson, Joseph. Hillside, Avon-road, Walthamstow, N.E.
1908. *Wilson, Malcolm, D.Sc., F.L.S., Lecturer in Mycology and Bacteriology in the University of Edinburgh. Royal Botanic Gardens, Edinburgh.
1909. §Wilson, R. A. Hinton, Londonderry.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1892. ‡Wilson, T. Stacey, M.D. 27 Wheeley's-road, Edgbaston, Birmingham.
1861. ‡Wilson, Thomas Bright. 13 Ashcroft-villas, Cirencester.
1887. §Wilson, W. Battlehillock, Kildrummy, Mossat, Aberdeenshire.
1909. ‡Wilson, W. Murray. 29 South Drive, Harrogate.
1910. §Wilton, T. R., M.A., Assoc. M.Inst.C.E. 18 Westminster-chambers, Crosshall-street, Liverpool.
1907. §Wimperis, H. E., M.A. 16 Reynolds-close, Hampstead-way, N.W.
1910. ‡Winder, B. W. Ceylon House, Sheffield.
1886. ‡WINDLE, Sir BERTRAM C. A., M.A., M.D., D.Sc., F.R.S., President of University College, Cork.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. (Local Sec. 1864.) 11 Cavendish-crescent, Bath.
1905. §Wiseman, J. G., F.R.C.S., F.R.G.S. Stranraer, St. Peter's-road, St. Margaret's-on-Thames.
1875. ‡WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1898; Council, 1899-1903, 1909-10.) Delahay House, 15 Chelsea Embankment, S.W.
1905. ‡Wood, A., jun. Emmanuel College, Cambridge.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1875. *Wood, George William Rayner. Singleton Lodge, Manchester.
1878. ‡WOOD, Sir H. TRUEMAN, M.A. Royal Society of Arts, John-street, Adelphi, W.C.; and Prince Edward's-mansions, Bayswater, W.
1908. ‡Wood, Sir Henry J. 4 Elsworthy-road, N.W.
1883. *Wood, J. H. 21 Westbourne-road, Birkdale, Lancashire.
1912. §Wood, John K. 304 Blackness-road, Dundee.
1904. *WOOD, T. B., M.A., Professor of Agriculture in the University of Cambridge. Caius College, Cambridge.
1899. *Wood, W. Hoffman. Ben Rhydding, Yorkshire.
1901. *Wood, William James, F.S.A. (Scot.) 266 George-street, Glasgow.
1899. *Woodcock, Mrs. E. M. Care of Messrs. Stilwell & Harley, 4 St. James'-street, Dover.
1896. *WOODHEAD, Professor G. SIMS, M.D. Pathological Laboratory, Cambridge.
1911. §Woodhead, T. W., Ph.D., F.L.S. Technical College, Huddersfield.
1912. *Wood-Jones, F., D.Sc. New Selma, Epsom, Surrey.
1906. *Woodland, Dr. W. N. F. Zoological Department, The Muir Central College, Allahabad, United Provinces, India.
1904. §Woodrow, John. Berryknowe, Meikleriggs, Paisley.
1904. ‡Woods, Henry, M.A. Sedgwick Museum, Cambridge.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, E.C.
1887. *WOODWARD, ARTHUR SMITH, LL.D., F.R.S., F.L.S., F.G.S. (Pres. C, 1909; Council, 1903-10), Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1869. *WOODWARD, C. J., B.Sc., F.G.S. The Lindens, St. Mary's-road, Harborne, Birmingham.

Year of Election

1912. §Woodward, Mrs C. J. The Lindens, St. Mary's-road, Harborne, Birmingham
1886 ‡Woodward, Harry Page, F G S. 129 Beaufort-street, S W.
1866. ‡WOODWARD, HENRY, LL D, F R S, F G S (Pres C, 1887; Council, 1887-94) 13 Arundel-gardens, Notting Hill, W.
1870. ‡WOODWARD, HORACE B, F R S, F G S 85 Coombe-road, Croydon.
1894. *Woodward, John Harold 8 Queen Anne's-gate, Westminster, S W
1909. *Woodward, Robert S. Carnegie Institution, Washington, U S A.
1908 §WOOLACOTT, DAVID, D Sc, F G S 8 The Oaks West, Sunderland.
1890. *Woollcombe, Robert Lloyd, M A, LL D, F I Inst., F R C Inst, F.R G.S, F.R E S, F.S S, M R I A 14 Waterloo-road, Dublin
1883 *Woolley, George Stephen Victoria Bridge, Manchester
1912 *Wordie, James M, B A St John's College, Cambridge.
1908. ‡Worsdell, W. C 2 Woodside, Bathford, Bath
1863 *Worsley, Philip J Rodney Lodge, Clifton, Bristol
1901 ‡Worth, J T Oakenrod Mount, Rochdale
1904 ‡WORTHINGTON, A M., C B, F R S 5 Louisa-terrace, Exmouth
1908. *Worthington, James H, M A, F R A S, F R G S. Wycombe Court, High Wycombe
1906 ‡WRAGGE, R H VERNON York
1910 ‡Wrench, E G. Park Lodge, Baslow, Derbyshire
1906 ‡Wright, Sir A E, M D, D Sc, F R S 6 Park-crescent, W.
1883. *Wright, Rev Arthur, D D Queens' College, Cambridge
1909 ‡Wright, C. S, B A Caius College, Cambridge.
1905 **Wright, FitzHerbert The Hayes, Alfreton*
1874 ‡Wright, Joseph, F G S 4 Alfred-street, Belfast.
1884 ‡WRIGHT, Professor R RAMSAY, M A, B Sc University College, Toronto, Canada
1904 ‡Wright, R T Goldieslie, Trumpington, Cambridge
1911. §Wright, W B, B A, F G S 14 Hume-street, Dublin.
1903 ‡Wright. William The University, Birmingham
1871. ‡WRIGHTSON, Sir THOMAS, Bart, M Inst C E, F G S Neasham Hall, Darlington
1902 ‡Wyatt, G H 1 Maurice-road, St Andrew's Park, Bristol
1901 ‡Wylie, Alexander Kirkfield, Johnstone, N B
1902 ‡Wylie, John 2 Mafeking-villas, Whitehead, Belfast
1911 §Wyllie, W L, R A Tower House, Tower-street, Portsmouth
1899. ‡WYNNE, W P, D Sc, F R S, Professor of Chemistry in the University of Sheffield 17 Taptonville-road, Sheffield

1901. *Yapp, R H, M A, Professor of Botany in University College, Aberystwyth
. *Yarborough, George Cook Camp's Mount, Doncaster.
1894. *Yarrow, A F Campsie Dene, Blanefield, Stirlingshire.
1905 ‡Yerbury, Colonel Army and Navy Club, Pall Mall, S W.
1909. §Young, Professor A. H. Trinity College, Toronto, Canada.
1904 ‡Young, Alfred Selwyn College, Cambridge
1891. §YOUNG, ALFRED C, F C S 17 Vicar's-hill, Lewisham, S E
1905 ‡Young, Professor Andrew, M A, B Sc South African College, Cape Town
1909. ‡Young, F. A. 615 Notre Dame-avenue, Winnipeg, Canada.
1894 *YOUNG, GEORGE, Ph D. 46 Church-crescent, Church End, Finchley, N.

Year of Election

1909. §Young, Herbert, M.A., B.C.L., F.R.G.S. Arnprior, Ealing, W.
1901 *Young, John. 2 Montague-terrace, Kelvinside, Glasgow.
1885 ‡YOUNG, R. BRUCE, M.A., M.B. 8 Crown-gardens, Dowanhill, Glasgow
1909. ‡Young, R. G. University of North Dakota, North Chautauqua, North Dakota, U.S.A.
1901. ‡Young, Robert M., B A Rathvarna, Belfast
1883. *YOUNG, SYDNEY, D Sc., F.R.S. (Pres B, 1904), Professor of Chemistry in the University of Dublin. 12 Raglan-road, Dublin.
1887. ‡Young, Sydney 29 Mark-lane, E.C.
1911 §Young, T. J College of Agriculture, Holmes Chapel, Cheshire.
1907 *YOUNG, WILLIAM HENRY, M A , Sc D , F.R S. La Nonette de la Forêt, Geneva, Switzerland.
1903 ‡Yoxall, Sir J. H., M.P 67 Russell-square, W.C.

CORRESPONDING MEMBERS

Year of Election

1887 Professor Cleveland Abbe Local Office, U S A. Weather Bureau, Washington, U S.A

1892 Professor Svante Arrhenius The University, Stockholm (Bergsgatan 18)

1897. Professor Carl Barus Brown University, Providence. R I, U S A

1887 Hofrath Professor A Bernthsen, Ph D Anilenfrabrik, Ludwigshafen, Germany

1894 Deputy Surgeon-General J S Billings, M D 476 Fifth-avenue, New York, U S A

1890 Professor Dr L Brentano Friedrichstrasse 11, Munchen

1893 Professor Dr W C Brogger Universitets Mineralogske Institute, Christiania, Norway

1894 Professor D H Campbell Stanford University, Palo Alto, California, U S A

1897. M C de Candolle 3 Cour de St Pierre, Geneva, Switzerland

1887. Professor G Capellini 65 Via Zamboni, Bologna, Italy.

1894 Emile Cartailhac 5 rue de la Chaine, Toulouse, France

1901 Professor T C Chamberlin Chicago, U S A

1894. Dr A Chauveau 7 rue Cuvier, Paris

1887. F W Clarke United States Geological Survey, Washington, D C, U S A

1873 Professor Guido Cora Via Nazionale 181, Rome

1889 W H Dall, Sc D United States Geological Survey, Washington, D C, U S A

1872 Dr Yves Delage Faculté des Sciences, La Sorbonne, Paris

1901 Professor G Dewalque 17 rue de la Paix, Liège, Belgium

1890 Professor V. Dwelshauvers-Dery 4 quai Marcellis, Liège, Belgium.

1876. Professor Alberto Eccher Florence

1894. Professor Dr. W Einthoven. Leiden, Netherlands.

1892. Professor F. Elfving Helsingfors, Finland

1901. Professor J. Elster. Wolfenbuttel, Germany.

1901. Professor W. G. Farlow. Harvard, U S A

1874. Dr. W Feddersen Carolinenstrasse 9, Leipzig

1886. Dr. Otto Finsch Altewiekring, No 19b, Braunschweig, Germany.

1894. Professor Wilhelm Foerster, D C L Encke Platz 3A, Berlin, S W. 48.

1872. W. de Fonvielle 50 rue des Abbesses, Paris.

1901. Professor A. P. N Franchimont. Leiden, Netherlands

1894. Professor Léon Fredericq 20 rue de Pitteurs, Liège, Belgium

1887. Professor Dr. Anton Fritsch 66 Wenzelsplatz, Prague, Bohemia

1892. Professor Dr Gustav Fritsch Berlinerstrasse 30, Berlin.

1881. Professor C M Gariel 6 rue Edouard Détaille, Paris.

1901. Professor Dr. H. Geitel Wolfenbuttel, Germany.

1889. Professor Gustave Gilson. l'Université, Louvain, Belgium.

1889. A. Gobert. 222 Chaussée de Charleroi, Brussels

Year of Election

1884 General A. W. Greely, LL D. War Department, Washington, U.S.A.
1892. Dr C E Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876 Professor Ernst Haeckel Jena
1881. Dr. Edwin H. Hall 30 Langdon-street, Cambridge, Mass, U S A.
1893 Professor Paul Heger. 23 rue de Drapiers, Brussels
1894. Professor Ludimar Hermann. Universitat, Konigsberg, Prussia
1893. Professor Richard Hertwig Zoologisches Institut, Alte Akademie, Munich
1893 Professor Hildebrand Stockholm
1897. Dr G W Hill. West Nyack, New York, U S A
1881. Professor A A W. Hubrecht, LL D, D Sc, C M Z S The University, Utrecht, Netherlands
1887 Dr Oliver W Huntington Cloyne House, Newport, R I, U S A
1884 Professor C Loring Jackson. 6 Boylston Hall, Cambridge, Massachusetts, U S A
1876. Dr W J Janssen Villa Polar, Massagno, Lugano, Switzerland
1881. W Woolsey Johnson, Professor of Mathematics in the United States, Naval Academy, Annapolis, Maryland, U S A.
1887. Professor C Julin 159 rue de Fragnée, Liège
1876 Dr Giuseppe Jung Bastions Vittoria 41, Milan
1884. Baron Dairoku Kikuchi, M A Imperial University, Tokyo, Japan.
1873 Professor Dr Felix Klein Wilhelm-Weberstrasse 3, Gottingen
1894 Professor Dr L Kny Kaiser-Allee 186–7, Wilmersdorf, bei Berlin
1894 Professor J Kollmann St Johann 88, Basel, Switzerland
1894 Maxime Kovalevsky 13 Avenue de l'Observatoire, Paris, France
1877 Dr Hugo Kronecker, Professor of Physiology Universitat, Bern, Switzerland
1887. Professor J W Langley 2037 Geddes-avenue, Ann Arbor, Michigan, U S A
1872 M Georges Lemoine 76 rue Notre Dame des Champs, Paris
1901 Professor Philipp Lenard Schlossstrasse 7, Heidelberg
1887 Professor A Lieben Molkerbastei 5, Vienna
1883 Dr. F Lindemann Franz-Josefstrasse 12/I, Munich
1887 Professor Dr. Georg Lunge Ramistrasse 56, Zurich, V
1894 Professor Dr Otto Maas Universitat, Munich
1887 Henry C McCook, D D, Sc D, LL D 3700 Chestnut street, Philadelphia, U S A
1887. Dr C A von Martius Voss-strasse 8, Berlin, W
1884 Professor Albert A Michelson The University, Chicago, U S A
1887. Dr Charles Sedgwick Minot Boston, Massachusetts, U S A
1894 Professor G Mittag-Leffler Djursholm, Stockholm
1897 Professor Oskar Montelius St Paulsgatan 11, Stockholm, Sweden
1897 Professor E W Morley, LL D West Hartford, Connecticut, U S A
1887 E S Morse Peabody Academy of Science, Salem, Mass, U S A
1889 Dr F. Nansen Lysaker, Norway
1894 Professor R Nasini Istituto Chimico, Via S Maria, Pisa, Italy.
1887 Professor Emilio Noelting. Muhlhausen, Elsass, Germany
1894 Professor H F Osborn Columbia College, New York, U S A.
1890 Professor W Ostwald. Linnéstrasse 2, Leipzig
1890 Maffeo Pantaleoni 13 Cola di Rienzo, Rome
1895 Professor F Paschen Universitat, Tubingen.
1887 Dr Pauli Feldbergstrasse 49, Frankfurt a/Main, Germany
1901. Hofrath Professor A Penck Georgenstrasse 34–36, Berlin, N W 7
1890. Professor Otto Pettersson. Stockholms Hogskola, Stockholm

Year of Election

1894. Professor W. Pfeffer, D C.L Linnéstrasse 11, Leipzig.
1886 Professor F. W. Putnam Harvard University, Cambridge, Massachusetts, U S A
1887 Professor Georg Quincke Bergstrasse 41, Heidelberg.
1868 L Radlkofer, Professor of Botany in the University of Munich Sonnenstrasse 7
1895 Professor Ira Remsen Johns Hopkins University, Baltimore, U S A
1897. Professor Dr. C. Richet 15 rue de l'Université, Paris, France.
1896. Dr van Rijckevorsel Parklaan 3, Rotterdam, Netherlands
1892. Professor Rosenthal, M D Erlangen, Bavaria
1895 Professor Carl Runge Wilhelm Weberstrasse 21, Gottingen, Germany
1901 Gen -Major Rykatchew. Central Physical Observatory, St Petersburg
1894 Professor P H Schoute The University, Groningen, Netherlands
1874. Dr G Schweinfurth Kaiser Friedrichstrasse 8, Berlin
1897. Professor W B Scott Princeton, N J , U S A
1887. Professor H Graf Solms Botanischer Garten, Strassburg.
1887. Ernest Solvay 25 rue du Prince Albert, Brussels
1888. Dr Alfred Springer 312 East 2nd-street, Cincinnati, Ohio, U S A
1881 Dr Cyparissos Stephanos The University, Athens
1881 Professor Dr Rudolf Sturm Weyderstrasse 9, Breslau
1887. Professor John Trowbridge Harvard University, Cambridge, Massachusetts, U S A
Arminius Vambéry, Professor of Oriental Languages in the University of Pesth, Hungary
1889 Wladimir Vernadsky Imperial Academy of Sciences, St Petersburg
1886 Professor Jules Vuylsteke 21 rue Belliard, Brussels, Belgium
1887 Professor H F Weber Zurich
1887 Professor Dr Leonhard Weber Moltkestrasse 60, Kiel
1887 Professor August Weismann Freiburg-im-Breisgau, Baden
1887. Dr H C White Athens, Georgia, U S A
1881. Professor H M Whitney. Branford, Conn , U S A
1887. Professor E Wiedemann Erlangen
1887. Professor Dr R Wiedersheim Hansastrasse 3, Freiburg im-Breisgau, Baden
1887. Dr Otto N Witt Ebereschen-Allée 10, Westend bei Berlin
1896 Professor E Zacharias Botanischer Garten, Hamburg.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED

GREAT BRITAIN AND IRELAND

Belfast, Queen's College.
Birmingham, Midland Institute
Bradford Philosophical Society
Brighton Public Library
Bristol Naturalists' Society
——, The Museum
Cambridge Philosophical Society
Cardiff, University College
Chatham, Royal Engineers' Institute
Cornwall, Royal Geological Society of
Dublin, Geological Survey of Ireland
——, Royal College of Surgeons in Ireland
——, Royal Irish Academy
——, Royal Society
Dundee, University College
Edinburgh Royal Society of
——, Royal Medical Society of
——, Scottish Society of Arts
Exeter, Royal Albert Memorial College Museum
Glasgow, Royal Philosophical Society of
——, Institution of Engineers and Shipbuilders in Scotland
Leeds, Institute of Science
——, Philosophical and Literary Society of
Liverpool, Free Public Library
——, Royal Institution
——, The University
London, Admiralty, Library of the
——, Board of Agriculture and Fisheries
——, Chemical Society
——, Civil Engineers, Institution of
——, Geological Society
——, Geology, Museum of Practical.
——, Greenwich, Royal Observatory
——, Guildhall Library
——, Institution of Electrical Engineers
——, Institution of Mechanical Engineers.
London, Intelligence Office, Central Department of Political Information.
——, King's College
——, Linnean Society
——, London Institution
——, Meteorological Office
——, Physical Society
——, Royal Anthropological Institute
——, Royal Asiatic Society
——, Royal Astronomical Society
——, Royal College of Physicians
——, Royal College of Surgeons
——, Royal Geographical Society
——, Royal Institution
——, Royal Meteorological Society
——, Royal Sanitary Institute
——, Royal Society
——, Royal Society of Arts
——, Royal Statistical Society
——, United Service Institution
——, University College
——, War Office, Library
——, Zoological Society
Manchester Literary and Philosophical Society
——, Municipal School of Technology.
Newcastle-upon-Tyne, Literary and Philosophical Society.
——, Public Library.
Norwich, The Free Library.
Nottingham, The Free Library
Oxford, Ashmolean Natural History Society
——, Radcliffe Observatory.
Plymouth Institution
——, Marine Biological Association
Salford, Royal Museum and Library
Sheffield, University College
Southampton, Hartley Institution
Stonyhurst College Observatory
Surrey, Royal Gardens, Kew
——, Kew Observatory, Richmond.
Swansea, Royal Institution of South Wales.
Yorkshire Philosophical Society
The Corresponding Societies.

EUROPE.

Berlin ....Die Kaiserliche Akademie der Wissenschaften.
Bonn ....University Library
Brussels ....Royal Academy of Sciences
Charkow ....University Library
Coimbra .....Meteorological Observatory
Copenhagen...Royal Society of Sciences
Dorpat, Russia University Library
Dresden ...Royal Public Library
Frankfort ...Natural History Society
Geneva. ....Natural History Society
Gottingen ....University Library
Gratz ......Naturwissenschaftlicher Verein
Halle ....Leopoldinisch-Carolinische Akademie
Harlem .....Société Hollandaise des Sciences
Heidelberg ...University Library
Helsingfors ...University Library
Jena .....University Library
Kazan, Russia University Library
Kiel . . . .Royal Observatory
Kiev .....University Library
Lausanne ...The University
Leiden . .....University Library
Liège ......University Library
Lisbon . .....Academia Real des Sciences
Milan ....The Institute
Modena . ....Royal Academy
Moscow .....Society of Naturalists
—— . ...University Library
Munich.......University Library.
Naples . .....Royal Academy of Sciences.
—— ....Zoological Station.
Paris. .....Association Française pour l'Avancement des Sciences
—— ....Geographical Society.
—— ....Geological Society
—— ....Royal Academy of Sciences
—— .. ..School of Mines
Pultova .... .Imperial Observatory,
Rome . .....Accademia dei Lincei.
—— ......Collegio Romano
—— .. .. Italian Geographical Society
—— .. ..Italian Society of Sciences
Roumania .Roumanian Association for the Advancement of Science
St Petersburg.University Library
—— ....Imperial Observatory.
Spain . Asociasion para el Progreso de las Ciencias
Stockholm . .Royal Academy
Turin .. Royal Academy of Sciences
Upsala . . .Royal Society of Science.
Utrecht .....University Library
Vienna ... .The Imperial Library
—— ..... Central Anstalt fur Meteorologie und Erdmagnetismus
Zurich.. ...Naturforschende Gesellschaft

ASIA

Agra . .....The College
Bombay .....Elphinstone Institution.
—— ....Grant Medical College.
Calcutta .....Asiatic Society
—— ....Hooghly College
Calcutta .. Medical College.
—— . .. Presidency College
Ceylon . . .The Museum, Colombo
Madras ..The Observatory
—— . ...University Library
Tokyo . .Imperial University.

AFRICA

Cape Town ....The Royal Observatory.
—— ....South African Association for the Advancement of Science.
—— ....South African Public Library
Grahamstown ..Rhodes University College.
Kimberley ....Public Library

AMERICA.

Albany ......The Institute.
Amherst......The Observatory.
Baltimore ....Johns Hopkins University.
Boston ......American Academy of Arts and Sciences.
—— ......Boston Society of Natural History.
California... .The University
—— .... .Lick Observatory
—— ......Academy of Sciences.
Cambridge ...Harvard University Library.
Chicago ......American Medical Association
—— ....Field Museum of Natural History
Kingston .....Queen's University
Manitoba ....Historical and Scientific Society
—— ....The University.
Massachusetts .Marine Biological Laboratory, Woods Holl.
Mexico ......Sociedad Científica 'Antonio Alzate'
Missouri .....Botanical Garden
Montreal .....Council of Arts and Manufactures
Montreal . ..McGill University.
New York ...American Society o Civil Engineers.
—— ....Academy of Sciences.
Ottawa.......Geological Survey of Canada.
Philadelphia ..American Philosophical Society.
—— ....Franklin Institute.
—— ....University of Pennsylvania.
Toronto .....The Observatory
—— ....The Canadian Institute.
—— ....The University.
Uruguay.. ...General Statistical Bureau and Library, Montevideo.
Washington...Board of Agriculture.
—— ...... Bureau of Ethnology.
—— ....Bureau of Standards, Department of Commerce and Labour.
—— . .....Coast and Geodetic Survey.
—— ....Library of Congress.
—— . . ...Naval Observatory.
—— ... Smithsonian Institution
—— ....United States Geological Survey of the Territories.

AUSTRALIA.

Adelaide .... Public Library of South Australia.
—— ....Royal Geographical Society.
Brisbane ... . Queensland Museum
Melbourne ...... Public Library
Sydney . ... Public Works Department.
—— ....Australian Museum.
—— .. . . .Library, Department of Mines.
Tasmania ....Royal Society
Victoria............The Colonial Government.

NEW ZEALAND.

Canterbury .... .. The Museum.
Wellington ....New Zealand Institute (Dominion Museum).

PRINTED BY
SPOTTISWOODE AND CO LTD, LONDON
COLCHESTER AND ETON